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I served as Chief Examiner of the certified court interpreter test for the State of California and as a contract translator and interpreter for various federal agencies through the U.S. Department of State for more than a decade. I served as an instructor at the University of California at Berkeley and the Middlebury Institute of International Studies at Monterey (MIIS) Graduate Program in Translation.

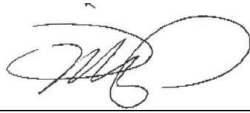
I have more than 30 years of experience reviewing thousands of technical, legal, and business documents from Japanese to English submitted to, among others, Japanese judicial authorities, U.S. federal courts, the U.S. International Trade Commission (ITC), and the USPTO Patent Trial and Appeal Board (PTAB).

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I certify under penalty of perjury that the foregoing is true and correct.

Executed this 3rd day of August 2024 in Contra Costa County of the State of California.

By:



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(19) Japanese Patent
Office (JP)

(12) **Patent Application Gazette** (A)

(11) Published Appl. No.

JPA H09-245964

(43) Appl. Published: Sept. 19, 1997

(51) Int. Cl. ⁶	ID Number	Office reference number	FI	Theme code (ref.)
H 05 B	33/10		H 05 B	33/10
Request for Examination: No			Number of Claims: 6 FD Total pages: 10	
(21) Filed Appl. No.: H08-80813		(71) Applicant: 000002185 Sony Corporation 7-35, Kita-Shinagawa 6-chome, Shinagawa-ku, Tokyo (72) Inventor: KIJIMA Yasunori c/o Sony Corporation, 6-7-35 Kitashinagawa, Shinagawa-ku, Tokyo (74) Agent or Attorney: OSAKA Hiroshi, Patent Attorney		
(22) Filed: Mar. 8, 1996				
(54) [TITLE OF THE INVENTION]		METHOD FOR MANUFACTURING SEMICONDUCTOR ELEMENT		

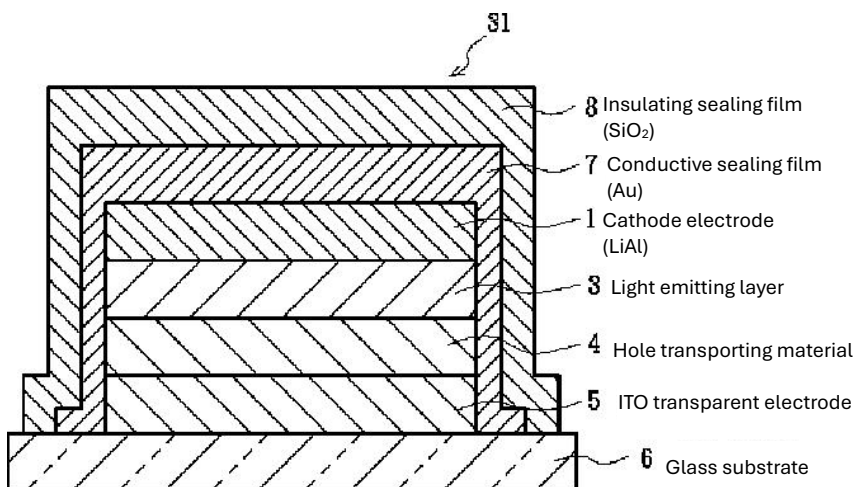
(57) SUMMARY

[PROBLEM]

To provide a method for producing an optical element which exhibits good stability even in the atmosphere and has a long life.

[RESOLUTION MEANS]

A conductive sealing film 7 and an insulating sealing film 8 are successively formed on a metal electrode 1 provided on a laminate body of organic layers 2, 3, and 4 including a light-emitting layer, and film formation is continuously performed in the same vacuum deposition device 11 as the organic layers 2, 3, and 4 and the metal electrode 1.



PATENT CLAIMS

[Claim 1]

A method for producing an optical element in which an electrode is provided on a laminate body of an organic layer including a light emitting region, the method comprising: forming the electrode under vacuum film-forming conditions, and then forming at least a conductive sealing film thereon while maintaining the vacuum.

[Claim 2]

The method according to claim 1, wherein an insulating sealing film is formed on the conductive sealing film while maintaining the vacuum.

[Claim 3]

The method according to claim 1, wherein the conductive sealing film and the insulating sealing film are formed in sequence by a vacuum deposition method.

[Claim 4]

The method according to claim 1, further comprising: sequentially laminating an organic hole transport layer, an organic light emitting layer and/or an organic electron transport layer, a metal electrode, a conductive sealing film, and an insulating sealing film under vacuum film-forming conditions on a transparent electrode of an optically transparent substrate provided with the transparent electrode.

[Claim 5]

The method according to claim 4, wherein the organic electroluminescence element is constructed.

[Claim 6]

The method according to claim 5, configured as an element for a color display.

DETAILED DESCRIPTION OF THE INVENTION

[0001]

TECHNOLOGICAL FIELD

The present invention relates to a method for producing an optical element, for example, a self-luminous flat display, and particularly to a method for producing an optical element suitable for an organic electroluminescent display using an organic thin film as an electroluminescent layer.

[0002]

CONVENTIONAL TECHNOLOGY

In recent years, the importance of human-machine interfaces has increased, particularly in the case of multimedia oriented products. In order for humans to operate machines more comfortably and efficiently, it is necessary to retrieve information from the machine being operated accurately, concisely, instantly and in sufficient quantity. Therefore, research is being conducted into various display elements, including displays.

[0003] Moreover, as machines become smaller, the demand for smaller and thinner display elements is also increasing on a daily basis.

[0004] For example, there has been remarkable progress in miniaturizing laptop information processing devices with an integrated display element, such as a notebook personal computer or notebook word processors, or the like, and in conjunction, there has been great technological innovation in liquid crystal displays that serve as display elements.

[0005] Today, liquid crystal displays are used as interfaces for a variety of products, including laptop information processing devices, as well as many of the products we use every day, such as small televisions, clocks, and calculators.

[0006] Taking advantage of the characteristics of liquid crystal, namely low voltage operation and low power consumption, these liquid crystal displays have been researched as a core of the

display element and as an interface between humans and machines, from small to large-capacity display devices.

[0007] However, because this liquid crystal display is not self-luminous, a backlight is required, and driving this backlight requires more power than driving the liquid crystal. As a result, the usage time with built-in batteries, or the like is shortened, and there are restrictions on usage.

[0008] Furthermore, because liquid crystal displays have a narrow viewing angle, they are not suitable for use as large display elements such as large displays or the like. In addition, because the display method relies on the orientation of liquid crystal molecules, there is also a major problem in that the contrast changes depending on the angle, even within the viewing angle.

[0009] Furthermore, from the perspective of the driving method, an active matrix method, which is one type of driving method, demonstrates a response speed sufficient for handling moving images, but because this method uses a TFT (thin film transistor) driving circuit, increasing the screen size is difficult due to pixel defects. The use of a TFT driving circuit is not preferable from the viewpoint of reducing cost.

[0010] The simple matrix method, another type of driving method, has low cost and allows relatively easy enlargement of screen size, but also has a problem in that it does not have sufficient response speed to handle moving images.

[0011] On the other hand, self-luminous display elements such as plasma display elements, inorganic electroluminescent elements, organic electroluminescent elements, and the like are being researched.

[0012] A plasma display element uses plasma light emission in a low pressure gas for display, and is suitable for large size and large capacity, but has problems in terms of thinness and cost. In addition, a high-voltage AC bias is required for operation, making these displays unsuitable for portable devices.

[0013] Inorganic electroluminescent elements have been commercialized as green light emitting displays, but these elements are AC bias driven similar to plasma display elements, requiring several hundred volts for driving, and full colorization is thought to be difficult.

[0014] On the other hand, electroluminescence from organic compounds has been studied for a long time since the discovery in the early 1960s of the phenomenon of luminescence due to carrier injection into anthracene single crystals that emit strong fluorescence. However, because this luminescence is low luminance, monochromatic, and involves single crystals, only basic research has been performed on carrier injection into organic materials.

[0015] However, since 1987 when Tang et al. of Eastman Kodak announced an organic thin-film electroluminescent device with a layered structure having an amorphous light-emitting layer that could be driven at low voltage and emit light with high brightness, research and development has been actively conducted in various fields with regard to the emission of the three primary colors of R, G, and B, stability, increased brightness, layered structure, manufacturing method, and the like.

[0016] Furthermore, as is characteristic of organic materials, various new materials have been invented through molecular design, and the like, and research is now actively being conducted into applying organic electroluminescent display elements, which have excellent characteristics such as low DC voltage drive, thinness, and self-luminescence, to color displays.

[0017] An organic electroluminescent element (hereinafter sometimes referred to as organic EL element) has a film thickness of 1 μm or less, and has ideal characteristics as a self-luminous display device, such as converting electrical energy into light energy by injecting a current, and emitting light in a planar form.

[0018] FIG. 22 depicts an embodiment of a conventional organic EL element 10. The organic EL element 10 is configured such that an ITO (indium tin substrate) transparent electrode 5, a hole transport layer 4, a light emitting layer 3, an electron transport layer 2, and a negative electrode (for example, an aluminum electrode) 1 are successively formed on a transparent substrate (for example, a glass substrate) 6 by, for example, a vacuum deposition method.

[0019] Furthermore, by selectively applying a DC voltage 17 between the transparent electrode 5, which is a positive electrode, and the negative electrode 1, holes as carriers injected from the transparent electrode 5 move through the hole transport layer 4, and electrons injected from the negative electrode 1 move through the electron transport layer 2, causing electron-hole recombination, which generates light 18 with a prescribed wavelength, which can be observed from the transparent substrate 6 side.

[0020] The light emitting layer 3 may contain a light emitting substance such as anthracene, naphthalene, phenanthrene, pyrene, chrysene, perylene, butadiene, coumarin, acridine, stilbene, and the like. This substance can be contained in the electron transport layer 2.

[0021] FIG. 23 depicts another conventional example, in which the light emitting layer 3 is omitted and the electron transport layer 2 contains the aforementioned zinc complex or a mixture with a fluorescent substance, and an organic EL element 20 is depicted as being configured so that light emission 18 with a prescribed wavelength is generated from the interface between the electron transport layer 2 and the hole transport layer 4.

[0022] FIG. 24 depicts a specific example of the aforementioned organic EL element. In other words, a laminate body containing the organic layers (hole transport layer 4, light emitting layer 3, or electron transport layer 2) is disposed between the negative electrode 1 and the positive electrode 5, and these electrodes are arranged in a matrix of intersecting stripes. Signal voltages are applied in time series by a luminance signal circuit 40 and a control circuit 41 with a built-in shift register, so that light is emitted at each of the many intersecting points (pixels).

[0023] Therefore, this configuration can be used not only as a display, but also as an image playback device. Note that the aforementioned stripe pattern can be arranged for each of the colors red (R), green (G) and blue (B) to form a full-color or multi-color display.

[0024] In a display device using these organic EL elements and containing a plurality of pixels, the light emitting organic thin film layers 2, 3, and 4 are generally sandwiched between a transparent electrode 5 and a metal electrode 1, and emit light toward the transparent electrode 5 side.

[0025] However, the aforementioned organic EL elements still have unresolved problems.

[0026] For example, degradation of these organic electroluminescent devices is a major problem, and the causes of this degradation are thought to include thermal degradation of the organic materials due to heat generation

accompanying light emission, the effects of moisture and oxygen contamination during production, and peeling of the organic layer due to oxidation of the cathode electrode, but the exact cause is not clear, and is thought to be a combination of these factors.

[0027] When organic electroluminescent elements are applied to display devices and the like, the influence of the aforementioned factors on the life span of these elements is a major problem.

Therefore, there is desire to provide a sealing film to protect the organic layer and the metal electrode, and then to continuously fabricate a sealing film structure in a vacuum.

[0028] However, for example, when providing an insulating sealing film, it has been found that if the insulating sealing film is deposited in a vacuum deposition device, the effect of radiant heat during deposition of the insulating sealing film will be large, raising concerns about the effect on organic layers such as the light emitting layer.

[0029]

PROBLEMS TO BE SOLVED BY THE INVENTION

In light of the foregoing, an object of the present invention is to provide a method for producing a long-life optical element that hardly experiences degradation of the organic layer and exhibits favorable stability even under atmospheric conditions.

[0030]

MEANS FOR SOLVING THE PROBLEM

In other words, the present invention relates to a method for producing an optical element having an electrode provided on a laminate body of organic layers including a light emitting region, which includes forming the electrode under vacuum film-forming conditions, and then forming at least a conductive sealing film thereon while maintaining the vacuum (and preferably further forming an insulating sealing film thereon).

[0031]

FORM OF REDUCING THE INVENTION TO PRACTICE

In the production method of the present invention, an insulating sealing film is preferably formed on the conductive sealing film while maintaining a vacuum.

[0032] Furthermore, the conductive sealing film and an insulating sealing film are preferably successively formed by a vacuum deposition method.

[0033] Furthermore, in the aforementioned element, an organic hole transport layer, an organic light emitting layer and/or an organic electron transport layer, a metal electrode, a conductive sealing film and an insulating sealing film are preferably sequentially laminated under vacuum film forming conditions on a transparent electrode of an optically transparent substrate containing the transparent electrode.

[0034] Thereby, the aforementioned method is a suitable method for producing an organic electroluminescent device, which is suitable as a device for a color display.

[0035]

EMBODIMENTS OF THE INVENTION

Embodiments of the present invention will be described below in detail.

[0036] Embodiment 1

FIG. 1 is a cross-sectional view depicting an organic EL element 31 produced in accordance with the first embodiment. FIG. 1 may depict one of a large number of pixels PX formed in a dot pattern on a glass substrate 6, as depicted in FIG. 2.

[0037] As depicted in FIG. 1, the organic EL element of the present embodiment has a transparent electrode 5 (anode) made of ITO (Indium Tin Oxide), a hole transport layer 4, a light emitting layer 3 also serving as an electron transport layer, and an electrode 1 (cathode) made of a lithium-aluminum (LiAl) alloy laminated on a glass substrate 6, and constitutes a single hetero-type laminate body similar to that depicted in FIG. 23 described above.

[0038] A conductive sealing film 7 and an insulating sealing film 8 are successively formed on the electrode 1 so as to cover the side surfaces of the element. These sealing films were formed by using a vacuum deposition device described later and by the method of the present embodiment.

[0039] Note that the structure depicted in FIG. 1 can also be applied to a double hetero-type organic EL element depicted in FIG. 22 in which the electron transport layer 2 is independently provided.

[0040] FIG. 2 is a plan view depicting a specific example of an organic EL element 30 produced by a vacuum deposition device. In other words, an ITO transparent electrode 5 having a size l of 2 mm x 2 mm is deposited to a thickness of about 100 nm on a glass substrate 6 having a size L of 30 mm x 30 mm using the vacuum deposition device described above, and then SiO_2 9 is deposited on the entire surface, which is then etched into a prescribed pixel pattern to form a large number of openings 15, through which the transparent electrodes 5 are exposed.

Therefore, the organic layers 4, 3 and metal electrode 1 are successively formed using SiO_2 on a light emitting region (pixel) PX with a size of 2 mm x 2 mm using a deposition mask 22 as depicted in FIG. 3.

[0041] FIG. 3 is a plan view schematically depicting the positional relationship of various deposition masks used for producing the organic EL element in the present embodiment, and depicts the openings of each mask. In other words, the organic layers 4, 3 and electrode 1 are formed through the openings 22a of the mask 22, then the conductive sealing film 7 is formed in a strip shape on each element in the same row, perpendicular to the ITO transparent electrode 5, through the openings 23a of the mask 23, and finally the insulating sealing film 8 is formed on each element through the openings 24a of the mask 24, thereby producing an element having the shape depicted in FIG. 1.

[0042] These masks 22, 23, and 24 are arranged in a vacuum deposition device 11 as depicted in FIG. 4. A pair of supporting means 13 which are fixed under the arm 12 are provided inside the device, and a stage mechanism (not depicted) that can set the masks 22, 23, 24 with the transparent glass substrate 6 facing downward is provided between both supporting means 13, 13. Furthermore, a prescribed number of various deposition sources 28 are disposed below the glass substrate and the mask. Each deposition source is heated by a power source 29 using a resistance heating method. This heating can be performed as necessary using an EB (electron beam) heating method or the like.

[0043] Next, a specific production process for the organic EL element according to the present embodiment will be described.

[0044] FIG. 5 is a plan view, with some parts omitted, depicting a state in which an ITO transparent electrode 5 is vapor-deposited on the same glass substrate 6 as in FIG. 2 described above, and then SiO_2 9 is vapor-deposited over the entire

surface, which is then etched into a prescribed pixel pattern to form a plurality of openings 15, with the transparent electrode 5 exposed in the openings 15. Furthermore, the production steps depicted in FIGS. 6 to 11 are depicted in the A-A cross section of FIG. 5a.

[0045] First, as depicted in FIG. 5, SiO_2 9 was deposited onto an ITO transparent electrode 5 having a film thickness of about 100 nm provided on a 30 mm x 30 mm glass substrate 6, and then patterned to produce a cell for producing an organic EL element in which the entire area except for a 2 mm x 2 mm light emitting region 15 was masked.

[0046] Thereby the state depicted in FIG. 8 is formed. In other words, FIG. 6 is a cross-sectional view along line A-A in FIG. 5, and FIG. 7 is a cross-sectional view along line VII-VII in FIG. 6, both of which depict the state in which the ITO transparent electrode 5 is formed, and FIG. 8 shows the state in which SiO_2 has been vapor-deposited on the transparent electrode 5 and patterned.

[0047] Next, the cell prepared as described above was placed in the vacuum deposition device depicted in FIG. 4, and TPD (N,N'-diphenyl-N,N'-di(3-methylphenyl)4,4'-diaminobiphenyl) (see the structural formula in FIG. 15) was deposited in a vacuum to a thickness of about 50 nm (deposition rate: 2 to 4 Å/sec) using a deposition mask 22 as depicted in FIG. 9 by the vacuum deposition method. As a result, TPD was deposited through the openings 22a of the mask 22 to form the hole transport layer 4. [0048] Next, using the same deposition mask, an aluminum-quinoline complex, Alq₃ (tris(8-quinolinol)aluminum) (see structural formula in FIG. 14), was deposited on the hole transport layer 4 deposited as described above, to a thickness of approximately 50 nm (deposition rate: 2 to 4 Å/sec) to form a light emitting layer (which also served as an electron transport layer: the same applies hereinafter) 3.

[0049] Next, using the same deposition mask, a LiAl alloy (Li content: 2.5%) was deposited on the light emitting layer 3 to a thickness of about 2 kÅ (deposition rate: 11 to 13 Å/sec) to form a metal electrode 1 as a cathode.

[0050] Next, as depicted in FIG. 10, the mask was changed to deposition mask 23 and gold (Au) was deposited on the metal electrode 1 to a thickness of about 10 kÅ (deposition rate: 30 to 40 Å/sec). As a result, gold was deposited through the openings 23a of the mask 23 to form a conductive sealing film 7 so as to cover the surface of the laminate body of the organic layers 4, 3 and the electrode 1, as depicted in the figure.

[0051] Finally, as depicted in FIG. 11, the mask was changed to deposition mask 24, and SiO_2 was deposited on the conductive sealing film 7 to a thickness of 2 kÅ (deposition rate: 50 to 60 Å/sec). As a result, SiO_2 was deposited through the openings 24a of the mask 24 to form an insulating sealing film 8 covering the conductive sealing film 7, thereby producing an organic EL element 31 as depicted in FIG. 1.

[0052] In this manner, in this embodiment, layers from the organic layers to the insulating sealing film were deposited continuously (in a vacuum integrated process) in the same vacuum deposition device by simply changing the deposition mask, and therefore the element can be produced without being exposed to atmospheric conditions during the element production process.

[0053] FIG. 12 is an enlarged cross-sectional view (corresponding to the cross section along line A-A in FIGS. 3 and 5) of a portion of FIG. 11 produced as described above, and FIG. 13 is a cross-sectional view (corresponding to the cross section along line B-B in FIGS. 3 and 5) of FIG. 12.

[0054] The organic EL element produced in this manner was left in air for one month after production, and then the properties of the element were measured. The luminance was found to be about 1200 cd/m² at an applied voltage of 6 V, which was almost the same as the result measured immediately after the element was produced. Furthermore, almost no dark spots were observed, and the sealing effect of the sealing films 7 and 8 was remarkable.

[0055] With this embodiment, the conductive sealing film 7 provided on the electrode 1 is continuously formed in the same vacuum deposition device. In addition to protecting the underlying organic layer and electrode and preventing oxidation of the electrode 1, the conductive sealing film 7 is further sealed with an insulating sealing film 8 made of SiO₂, which further enhances the effects of preventing oxidation of the electrode 1 and degradation of the organic layer.

[0056] Furthermore, since the conductive sealing film 7 made of gold is interposed under the insulating sealing film 8, degradation of the organic layer due to radiant heat during vapor deposition of the insulating sealing film 8 is prevented. Therefore, the conductive sealing film 7 must be thickly formed as a buffer layer during deposition, and the above thickness (about 10 kÅ) is sufficient.

[0057] When the conductive sealing film 7 is made of a material with good thermal conductivity such as a metal, efficient dissipation of the radiant heat can be expected, which is considered to be advantageous in preventing degradation of the organic layer.

[0058] Moreover, the organic layer and above are formed continuously in the same vacuum deposition device, so productivity is high and there is no effect of oxygen in the atmosphere during production. Furthermore, by using the aforementioned sealing films, an organic EL element having good stability even when used in air can be obtained.

[0059] The aforementioned effects of this embodiment can also be obtained in the other embodiments described below.

[0060] Embodiment 2

In this embodiment, the deposition mask 22 depicted in FIG. 9 was used to form the light emitting layer 3, similarly to the aforementioned embodiment 1. The materials used up to this light emitting layer 3 are the same as those in the first embodiment (the same applies to each of the embodiments described below), so a description thereof will be omitted.

[0061] Next, using the same deposition mask, a lithium-aluminum (LiAl) alloy (lithium content: 2.5%) was deposited on the light emitting layer 3 to a thickness of about 2 kÅ (deposition rate: 11 to 13 Å/sec) to form a metal electrode 1 as a cathode.

[0062] Next, the mask was changed to deposition mask 23 and gold (Au) was deposited on the metal electrode 1 to a thickness of about 10 kÅ (deposition rate: 30 to 40 Å/sec) to form the conductive sealing film 7.

[0063] Finally, the mask was changed to deposition mask 24, and alumina (Al₂O₃) was deposited on the conductive sealing film 7 to a thickness of 2 kÅ (deposition rate 50 to 60 Å/sec) to form an insulating sealing film 8, thereby producing an organic EL element 32 as depicted in FIG. 16.

[0064] The organic EL element produced in this manner was left in air for one month after production, and then the properties of the element were measured. The luminance was found to be about 1100 cd/m² at an applied voltage of 6 V, which was almost the same as the result measured immediately after the element was produced. Furthermore, almost no dark spots were observed, and the sealing effect of the sealing films 7 and 8 was observed.

[0065] Embodiment 3

In this embodiment, a strontium-aluminum (SrAl) alloy (strontium content: 2%) was deposited as a cathode electrode to a thickness of about 2 kÅ (deposition rate: 11 to 13 Å/sec) using the same deposition mask on the light emitting layer 3 formed in the same manner as in embodiment 1.

[0066] Next, the mask was changed to deposition mask 23 and gold (Au) was deposited on the metal electrode 1 to a thickness of about 10 kÅ (deposition rate: 30 to 40 Å/sec) to form the conductive sealing film 7.

[0067] Finally, the mask was changed to deposition mask 24, and SiO₂ was deposited on the conductive sealing film 7 to a thickness of 2 kÅ (deposition rate 50 to 60 Å/sec) to form an insulating sealing film 8, thereby producing an organic EL element 33 as depicted in FIG. 17.

[0068] The organic EL element produced in this manner was left in air for one month after production, and then the properties of the element were measured. The luminance was found to be about 1000 cd/m² at an applied voltage of 7 V, which was almost the same as the result measured immediately after the element was produced. Furthermore, almost no dark spots were observed, and the sealing effect of the sealing films 7 and 8 was observed.

[0069] Embodiment 4

In this embodiment, a strontium-aluminum (SrAl) alloy (strontium content: 2%) was deposited as a cathode electrode to a thickness of about 2 kÅ (deposition rate: 11 to 13 Å/sec) using the same deposition mask on the light emitting layer 3 formed in the same manner as in embodiment 1.

[0070] Next, the mask was changed to deposition mask 23 and gold (Au) was deposited on the metal electrode 1 to a thickness of about 10 kÅ (deposition rate: 30 to 40 Å/sec) to form the conductive sealing film 7.

[0071] Finally, the mask was changed to deposition mask 24, and alumina (Al₂O₃) was deposited on the conductive sealing film 7 to a thickness of 2 kÅ (deposition rate 50 to 60 Å/sec) to form an insulating sealing film 8, thereby producing an organic EL element 34 as depicted in FIG. 18.

[0072] The organic EL element produced in this manner was left in air for one month after production, and then the properties of the element were measured. The luminance was found to be about 1200 cd/m² at an applied voltage of 8 V, which was almost the same as the result measured immediately after the element was produced, and thus a sealing effect was observed with both sealing films 7 and 8.

[0073] Comparative Example 1

In this comparative example, similar to embodiment 3, a strontium-aluminum (SrAl) alloy (strontium content: 2%) was deposited as a cathode electrode to a thickness of about 2 kÅ (deposition rate: 11 to 13 Å/sec) using the same deposition mask on the light emitting layer 3 formed in the same manner as in embodiment 1.

[0074] Finally, the mask was changed to deposition mask 24, and SiO₂ was deposited on the metal electrode 1 to a thickness of 2 kÅ (deposition rate 50 to 60 Å/sec) to form an insulating sealing film 8, thereby producing an organic EL element 35 as depicted in FIG. 19. Therefore, in this comparative example, the conductive sealing film 7 was not provided.

[0075] When the organic EL element thus produced was measured immediately after production, the organic layer had degraded due to radiant heat generated during deposition of the insulating sealing film 8, and almost no light was emitted. Therefore, the effect of providing the conductive sealing film adjacent to and below the insulating sealing film as in the aforementioned embodiment was demonstrated.

[0076] Comparative Example 2

In this comparative example, similar to embodiment 1, a lithium-aluminum (LiAl) alloy (lithium content: 2.5%) was deposited as a cathode electrode to a thickness of about 2 kÅ (deposition rate: 11 to 13 Å/sec) using the same mask on the light emitting layer 3 formed in the same manner as in embodiment 1.

[0077] Thereafter, the pressure inside the deposition device was temporarily returned from vacuum to atmospheric pressure, and then the device was again evacuated to a vacuum.

[0078] Next, the mask was changed to deposition mask 23 and gold (Au) was deposited on the metal electrode 1 to a thickness of about 10 kÅ (deposition rate: 30 to 40 Å/sec) to form the conductive sealing film 7.

[0079] Finally, the mask was changed to deposition mask 24, and SiO₂ was deposited on the conductive sealing film 7 to a thickness of 2 kÅ (deposition rate 50 to 60 Å/sec) to form an insulating sealing film 8, thereby producing an organic EL element 36 as depicted in FIG. 20.

[0080] The organic EL element produced in this manner was left in air for one month after production, and then the properties of the element were measured. The luminance was found to be about 500 cd/m² at an applied voltage of 13 V, but these results were greatly degraded from the result measured immediately after the element was produced. Furthermore, a large number of dark spots were observed.

[0081] In other words, the adverse effects of exposing the element to the atmosphere before the formation of the conductive sealing film 7 were evident, proving the importance of also forming the conductive sealing film 7 under vacuum conditions.

[0082] Comparative Example 3

In this comparative example, similar to embodiment 1, a lithium-aluminum (LiAl) alloy (lithium content: 2.5%) was deposited as a cathode electrode to a thickness of about 2 kÅ (deposition rate: 11 to 13 Å/sec) using the same mask on the light emitting layer 3 formed in the same manner as in embodiment 1.

[0083] Next, the mask was changed to deposition mask 23 and gold (Au) was deposited on the metal electrode 1 to a thickness of about 10 kÅ (deposition rate: 30 to 40 Å/sec) to form the conductive sealing film 7.

[0084] Thereafter, the pressure inside the deposition device was temporarily returned from vacuum to atmospheric pressure, and then the device was again evacuated to a vacuum.

[0085] Finally, the mask was changed to deposition mask 24, and SiO₂ was deposited on the conductive sealing film 7 to a thickness of 2 kÅ (deposition rate 50 to 60 Å/sec) to form an insulating sealing film 8, thereby producing an organic EL element 37 as depicted in FIG. 21.

[0086] The organic EL element produced in this manner was left in air for one month after production, and then the properties of the element were measured. The luminance was found to be about 900 cd/m² at an applied voltage of 9 V, but these results were degraded from the result measured immediately after the element was produced. Furthermore, there was also an increase in dark spots.

[0087] In other words, the adverse effects of exposing the element to the atmosphere before the formation of the insulating sealing film 8 were observed, proving the importance of forming all of the films under vacuum conditions.

[0088] Although the embodiments of the present invention were described above, the aforementioned embodiments can be modified in various ways based on the technical concepts of the present invention.

[0089] For example, the material of the anode electrode, the electron transport layer, the hole transport layer, and the cathode electrode can be appropriately selected and used. Hole transporting organic substances such as diamine derivatives, benzidine derivatives, styrylamine derivatives, triphenylmethane derivatives, and hydrazone derivatives may be used in the hole transport layer. Similarly, the electron transport layer may be made of an organic electron transport material such as a quinolinol derivative, a perylene derivative, a bisstyryl derivative, or a pyrazine derivative.

[0090] Furthermore, the light emitting layer may of course be a host-guest type light emitting layer, in which case the guest material may be any material that has sublimation properties, and is not limited to dyes having fluorescent properties. An example would be a pigment such as quinacridone.

[0091] The organic EL element may be a single hetero type in which the light emitting layer also functions as an electron transport layer or a hole transport layer.

[0092] Furthermore, in addition to the above-mentioned materials, the cathode electrode material is preferably a metal having a small work function from the vacuum level of the electrode material in order to efficiently inject electrons. Examples include low work function metals such as indium (In), magnesium (Mg), silver (Ag), calcium (Ca), barium (Ba), and lithium (Li), used alone or as an alloy with other metals to enhance stability.

[0093] Furthermore, with the present invention, ITO is used as the transparent electrode for the anode electrode in order to extract organic electroluminescence from the anode electrode side. However, of course, in order to efficiently inject holes, an anode electrode material having a large work function from the vacuum level, such as gold, a tin dioxide-antimony mixture ($\text{SnO}_2 + \text{Sb}$), or a zinc oxide-aluminum mixture ($\text{ZnO} + \text{Al}$), may also be used.

[0094] Furthermore, the conductive sealing film may be made of a material other than a metal material. For example, a conductive organic material containing polyoxadiazole may be vapor-deposited and then cured with ultraviolet light to perform vapor deposition polymerization. The conductive metal material may be any material that exhibits good electrical conductivity, and may be, for example, a metal such as tungsten (W), aluminum (Al), gold (Au), or silver (Ag), either alone or in the form of an alloy. Furthermore, a conductive sealing film such as a diamond-like carbon thin film doped with a minority carrier may be used. However, using a material that is not easily oxidized is preferable.

[0095] Furthermore, the material for the insulating sealing film can be any material that can be vapor-deposited, and can be prepared by resistance heating vapor deposition, electron beam heating vapor deposition, sputtering, or the like, using materials such as silicon monoxide (SiO), silicon dioxide (SiO_2), alumina (Al_2O_3), germanium dioxide (GeO_2), and aluminum nitride (AlN).

[0096] In the aforementioned embodiment, a mono-color organic EL element has primarily been described. However, by selecting a light emitting material, a full-color or multi-color organic EL element that emits the three colors R, G, and B can be produced by the aforementioned method. Additionally, the present invention can be applied to an organic EL element that can be used not only for displays, but also for light sources, as well as other optical applications.

[0097]

FUNCTION AND EFFECTS OF THE INVENTION

As described above, when manufacturing an optical element in which an electrode is provided on a laminate body of organic layers including a light emitting region, the electrode is formed under vacuum film-forming conditions, and then at least a conductive sealing film is formed thereon while maintaining the vacuum. Therefore the present invention prevents oxidation of the electrode due to the atmosphere, and also prevents degradation of the organic layer due to radiant heat during formation of the insulating sealing film on the conductive sealing film. Therefore, it is possible to provide an optical element that exhibits good stability even in air and that has a long life.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic cross-sectional view of an organic EL element according to an embodiment of the present invention.

FIG. 2 is a plan view of a specific embodiment of the organic EL element.

FIG. 3 is an enlarged plan view depicting the positional relationship of various masks used in manufacturing the organic EL element.

FIG. 4 is a schematic cross-sectional view of a vacuum deposition device used for production of the organic EL element.

FIG. 5 is a plan view depicting a state in which SiO_2 deposited on a glass substrate is etched into a prescribed pixel pattern when producing the organic EL element.

FIG. 6 is a schematic cross-sectional view of main parts depicting one stage of a production process of the organic EL element.

FIG. 7 is a cross-sectional view along line VII-VII in FIG. 6.

FIG. 8 is a schematic cross-sectional view of main parts depicting another stage of the production process.

FIG. 9 is a schematic cross-sectional view of main parts depicting another stage of the production process.

FIG. 10 is a schematic cross-sectional view of main parts depicting another stage of the production process.

FIG. 11 is a schematic cross-sectional view of main parts depicting yet another stage of the production process.

FIG. 12 is an enlarged cross-sectional view depicting main parts of a completed organic EL element.

FIG. 13 is a cross-sectional view along line XIII-XIII in FIG. 12.

FIG. 14 depicts the structural formula of an aluminum-quinoline complex used as a light emitting layer material of the organic EL element.

FIG. 15 depicts the structural formula of TPD used as a hole transport layer material in the organic EL element.

FIG. 16 is a schematic cross-sectional view of an organic EL element according to another embodiment of the present invention.

FIG. 17 is a schematic cross-sectional view of an organic EL element according to another embodiment of the present invention.

FIG. 18 is a schematic cross-sectional view of an organic EL element according to yet another embodiment of the present invention.

FIG. 19 is a schematic cross-sectional view of an organic EL element according to a comparative example of the present invention.

FIG. 20 is a schematic cross-sectional view of an organic EL element according to another comparative example of the present invention.

FIG. 21 is a schematic cross-sectional view of an organic EL element according to yet another comparative example of the present invention.

FIG. 22 is a schematic cross-sectional view depicting a conventional organic EL element.

FIG. 23 is a schematic cross-sectional view depicting another conventional organic EL element.

FIG. 24 is a schematic perspective view depicting a specific example of the organic EL element.

DESCRIPTION OF REFERENTIAL NUMERALS AND CODES

1. Electrode (cathode), 2. Electron transport layer, 3. Light emitting layer, 4. Hole transport layer, 5. ITO transparent electrode, 6. Glass substrate, 7. Conductive sealing film, 8. Insulating sealing film, 9. SiO_2 film, 11. Vacuum deposition device, 15. Opening, 22, 23, 24. Mask, 22a, 23a, 24a. Opening, 28. Deposition source, 29. Power source, 30, 31, 32, 33, 34, 35, 36, 37. Organic EL element, PX. Pixel

31

8 Insulating sealing Film (SiO_2)

7 Conductive sealing Film (Au)

1 Cathode electrode (LiAl)

3 Light emitting layer

4 Hole transporting material

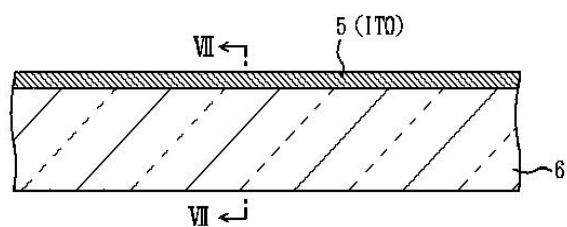
5 ITO transparent electrode

6 Glass substrate

Structural formula of Alq₃

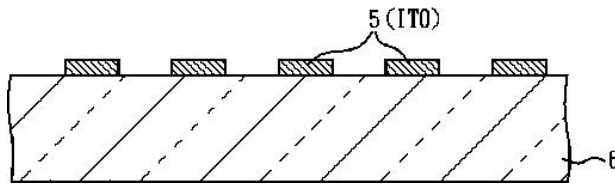
FIG. 1 is a schematic diagram of a system for measuring the thickness of a substrate. The diagram shows a cross-section of a substrate 11 with a top surface 12 and a bottom surface 13. A measurement unit 6 is positioned between the top and bottom surfaces. A light source 28 is located below the substrate, emitting light rays 22, 23, and 24 that pass through the substrate and are detected by a detector 29.

ITO sputtering

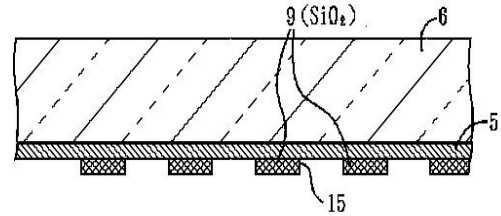


[FIG. 7]

ITO Etching

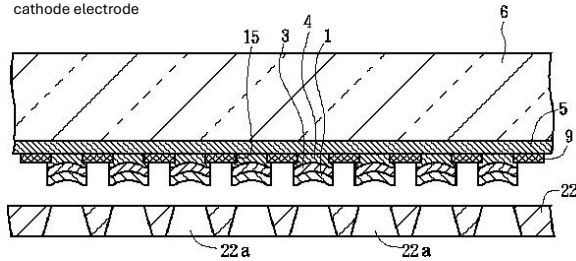


[FIG. 8]

SiO₂ deposition

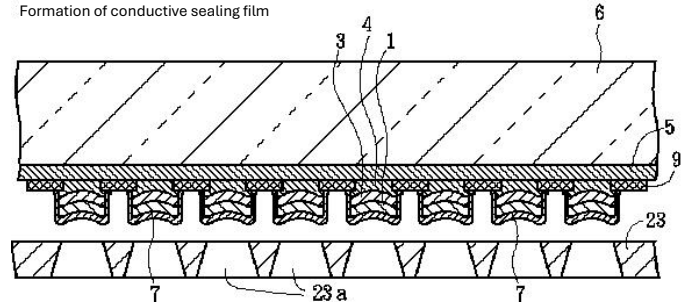
[FIG. 9]

Formation of hole transport layer to cathode electrode



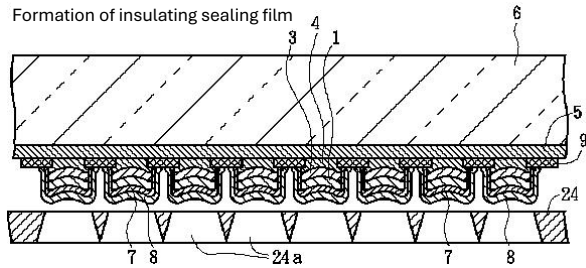
[FIG. 10]

Formation of conductive sealing film

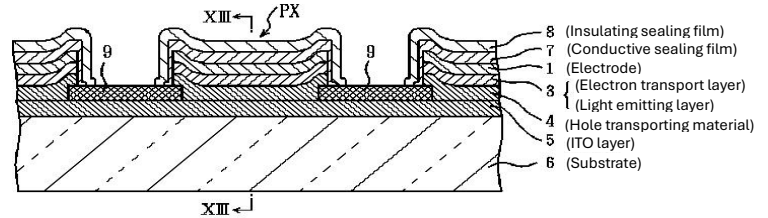


[FIG. 11]

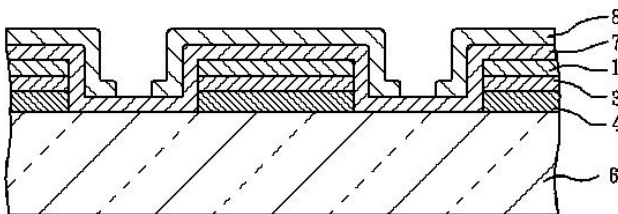
Formation of insulating sealing film



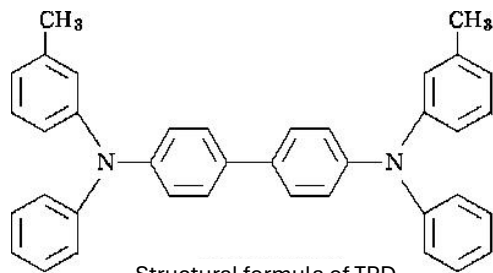
[FIG. 12]



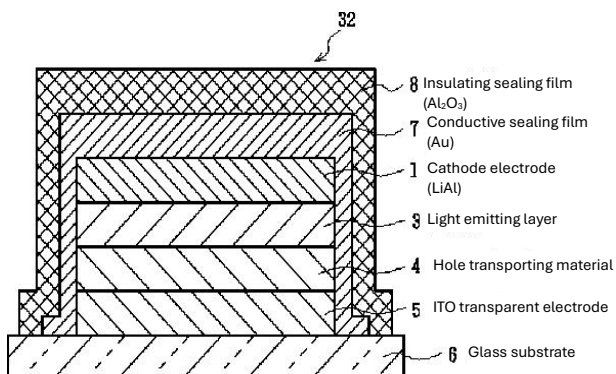
[FIG. 13]



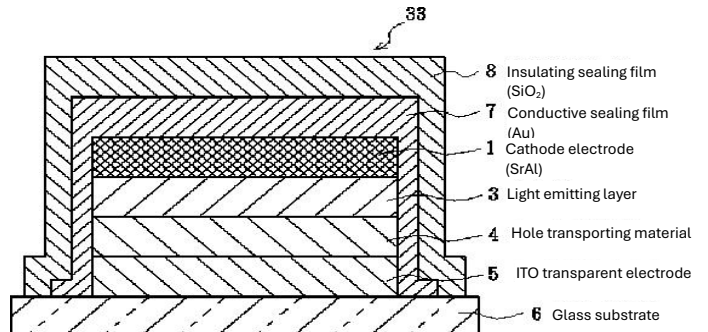
[FIG. 15]



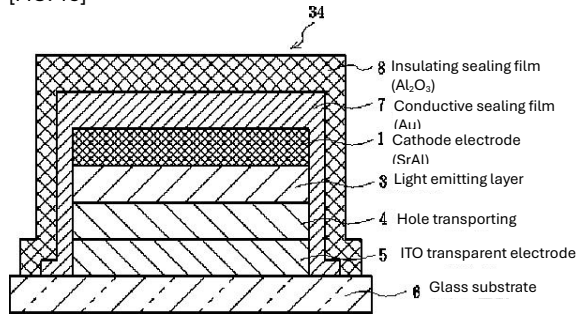
[FIG. 16]



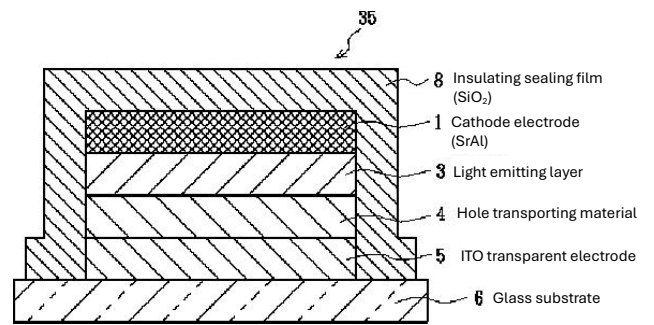
[FIG. 17]



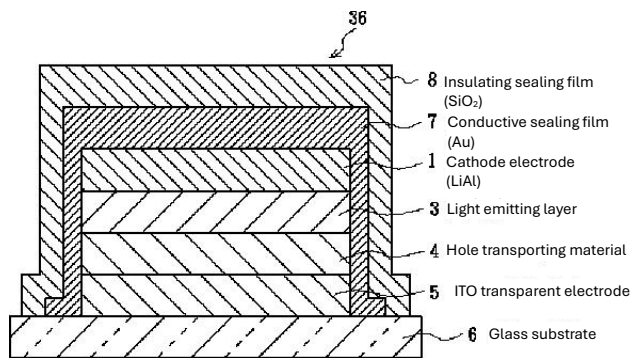
[FIG. 18]



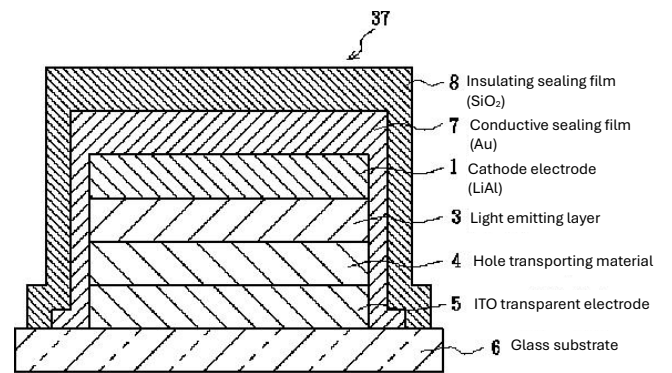
[FIG. 19]



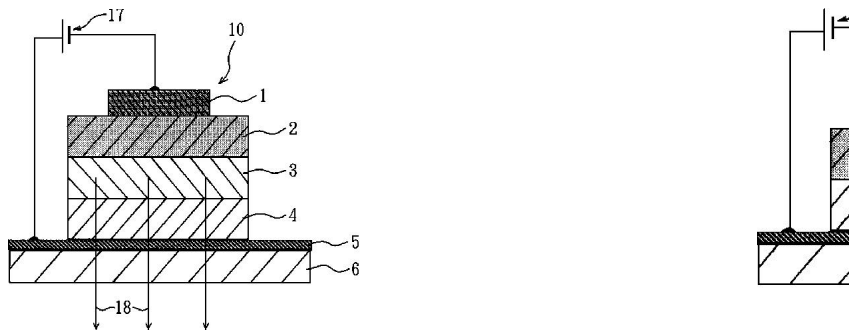
[FIG. 20]



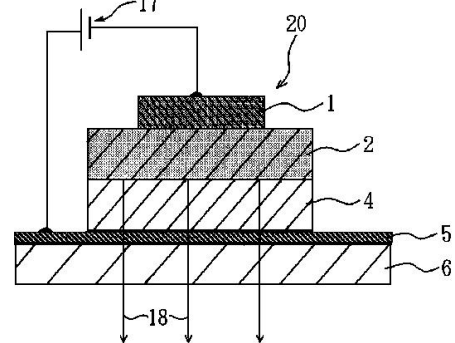
[FIG. 21]



[FIG. 22]



[FIG. 23]



[FIG. 24]

