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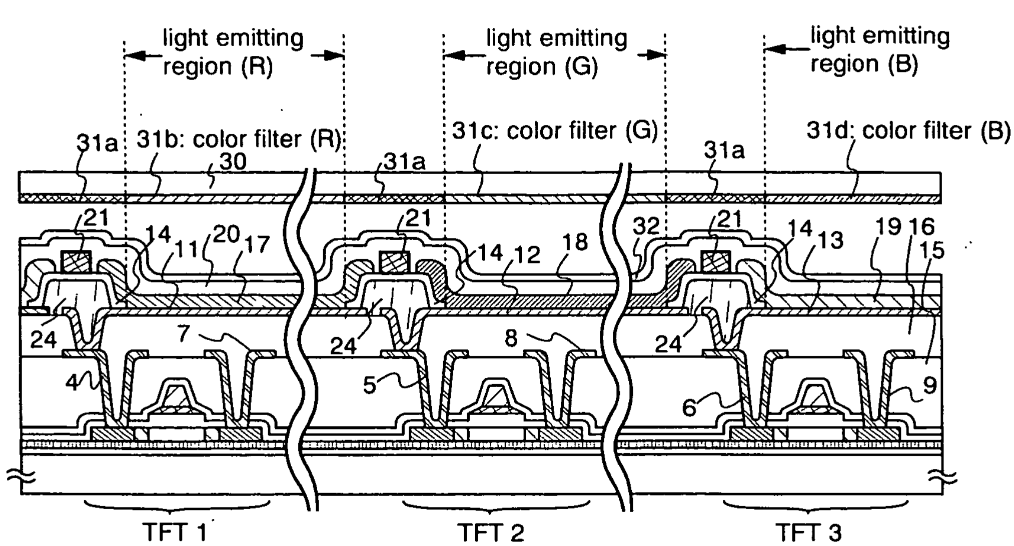
(54) Light emitting device and method of manufacturing the same

(57) To provide a light emitting device high in reliability with a pixel portion having high definition with a large screen. According to a light emitting device of the present invention, on an insulator (24) provided between pixel electrodes, an auxiliary electrode (21) made of a metal film is formed, whereby a conductive layer (20) made of a transparent conductive film in contact with the auxiliary electrode can be made low in resistance and thin. Also, the auxiliary electrode (21) is used to achieve connection with an electrode on a lower layer, whereby the electrode can be led out with the transparent conductive film formed on an EL layer. Further, a protective film (32) made of a film containing hydrogen and a silicon nitride film which are laminated is formed, whereby high reliability can be achieved.

FIG. 1A sectional view of A-A'



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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to a semiconductor device and, particularly, to a light emitting device having an organic light emitting element formed over a substrate having an insulating surface and a manufacturing method therefor. The present invention also relates to a module in which an IC etc. including a controller is mounted on a panel having the organic light emitting element. Note that, in this specification, the panel and the module which have the organic light emitting element are collectively referred to as a light emitting device. Further, the present invention relates to an apparatus for manufacturing the light emitting device.

[0002] Note that, in this specification, the term semiconductor device refers to the devices in general which can function by utilizing semiconductor characteristics. The light emitting device, an electro-optic device, a semiconductor circuit, and an electronic device are all included in the category of the semiconductor device.

2. Description of the Related Art

[0003] Techniques of forming TFTs (thin film transistors) on substrates have been progressing greatly in recent years, and developments in their application to active matrix display devices is advancing. In particular, TFTs that use polysilicon films have a higher electric field effect mobility (also referred to as mobility) than TFTs that use conventional amorphous silicon films, and therefore high speed operation is possible. Developments in performing control of pixels by forming driver circuits made from TFTs that use polysilicon films over a substrate on which the pixels are formed have therefore been flourishing. It has been expected that various advantages can be obtained by using active matrix display devices in which pixels and driver circuits are mounted on the same substrate, such as reductions in manufacturing cost, miniaturization of the display device, increases in yield, and increases in throughput.

[0004] Furthermore, research on active matrix light emitting devices using organic light emitting elements as self light emitting elements (hereinafter referred to simply as light emitting devices) has become more active. The light emitting devices are also referred to as organic EL displays (OELDs) and organic light emitting diodes (OLEDs).

[0005] TFT switching elements (hereinafter referred to as switching elements) are formed for each pixel in active matrix light emitting devices, and driver elements for performing electric current control using the switching TFTs (hereinafter referred to as electric current control TFTs) are operated, thus making EL layers (strictly speaking, light emitting layers) emit light. For example, a light emitting device disclosed in JP 10-189252 is known.

[0006] Organic light emitting elements are self light emitting, and therefore have high visibility. Backlights, necessary for liquid crystal display devices (LCDs), are not required for organic light emitting elements, which are optimal for making display devices thinner and have no limitations in viewing angle. Light emitting devices using organic light emitting elements are consequently being focused upon as substitutes for CRTs and LCDs.

[0007] Note that EL elements have a layer containing an organic compound in which luminescence develops by the addition of an electric field (Electro Luminescence) (hereinafter referred to as EL layer), an anode, and a cathode. There is light emission when returning to a base state from a singlet excitation state (fluorescence), and light emission when returning to a base state from a triplet excitation state (phosphorescence) in the organic compound layer, and it is possible to apply both types of light emission to light emitting devices manufactured by the manufacturing apparatus and film formation method of the present invention.

[0008] EL elements have a structure in which an EL layer is sandwiched between a pair of electrodes, and the EL layer normally has a laminate structure. A "hole transporting layer / light emitting layer / electron transporting layer" laminate structure can be given as a typical example. This structure has extremely high light emitting efficiency, and at present almost all light emitting devices undergoing research and development employ this structure.

[0009] Further, a structure in which: a hole injecting layer, a hole transporting layer, a light emitting layer, and an electron transporting layer are laminated in order on an anode; or a hole injecting layer, a hole transporting layer, a light emitting layer, an electron transporting layer, and an electron injecting layer are laminated in order on an anode may also be used. Fluorescent pigments and the like may also be doped into the light emitting layers. Further, all of the layers may be formed by using low molecular weight materials, and all of the layers may be formed by using high molecular weight materials.

[0010] The conventional active matrix type light emitting device is composed of a light emitting element in which an electrode electrically connected with TFT on the substrate is formed as an anode, then the organic compound layer was formed on the anode. Light generated at the organic compound layer is radiated from the anode that is a transparent electrode to TFT.

[0011] However, in this structure, the problem has arisen when the resolution is intended to be risen that an aperture ratio is limited due to an arrangement of TFT and wirings in the pixel unit.

SUMMARY OF THE INVENTION

[0012] According to the present invention, manufactured is an active matrix light emitting device having the light emitting element with a structure in which an electrode on the TFT side electrically connected to the TFT on the substrate is formed as a cathode, on which an organic compound layer and an anode as a transparent electrode are formed in the stated order (hereinafter, referred to as upper surface emission structure). Alternatively, manufactured is an active matrix light emitting device having the light emitting element with a structure in which an electrode on the TFT side electrically connected to the TFT on the substrate is formed as an anode, on which an organic compound layer and a cathode as a transparent electrode are formed in the stated order (hereinafter, also referred to as upper surface emission structure).

[0013] In the above-mentioned respective structures, there arises a problem concerning a higher film resistance of a transparent electrode. In particular, when a film thickness of the transparent electrode is reduced, the film resistance further increases. If the film resistance of the transparent electrode serving as an anode or a cathode is increased, there arises a problem in that a potential distribution in the surface becomes nonuniform due to voltage drop, which involves variations in luminance of the light emitting element. Accordingly, an object of the present invention is to provide a light emitting device having a structure useful in decreasing the film resistance of the transparent electrode of the light emitting element and a manufacturing method therefor and further to provide an electronic device using the above light emitting device as a display portion.

[0014] In addition, another object of the present invention is to increase reliability in the light emitting element and the light emitting device.

[0015] According to the present invention, in manufacturing the light emitting element formed over the substrate, a conductive film is formed on an insulator arranged between pixel electrodes prior to formation of an organic compound layer for the purpose of suppressing the film resistance of the transparent electrode.

[0016] Further, the present invention is characterized in that a lead wiring is formed using the above conductive film to achieve connection with other wirings on a lower layer as well.

[0017] According to a structure of the invention disclosed in this specification, there is provided a light emitting device, including:

a pixel portion having a plurality of light emitting elements each including: a first electrode; an organic compound layer formed on the first electrode in contact therewith; and a second electrode formed on the organic compound layer in contact therewith;
a driver circuit; and
a terminal portion,

the device being characterized in that:

in the pixel portion, end portions of the first electrode connected to a thin film transistor are covered with an insulator, a third electrode made of a conductive material is formed on the insulator, the organic compound layer is formed on the insulator and the first electrode, and the second electrode is formed on the organic compound layer and the third electrode in contact therewith; and
a portion where a wiring made of a material identical to that of the third electrode or that of the second electrode is connected with a wiring extended from a terminal is formed between the terminal portion and the pixel portion.

[0018] In the above-mentioned structure, the third electrode may have a pattern shape identical to that of the insulator. In this case, it is formed using a mask identical to that of the insulator.

[0019] Alternatively, in the above-mentioned structure, the third electrode may have a pattern shape different from that of the insulator. In this case, after patterning the insulator, a film made of a conductive material is formed to form the third electrode using a mask different from that used for patterning the insulator.

[0020] Also, according to another structure of the present invention, in manufacturing a light emitting element formed over a substrate, a conductive film is formed on an insulator arranged between pixel electrodes prior to formation of the organic compound layer, and after the organic compound layer and a transparent electrode are formed, an electrode made of a material high in conductivity is formed on the transparent electrode to realize low film resistance of the transparent electrode. Note that, the electrode formed on the transparent electrode is not formed in a portion serving as a light emitting region. Further, the present invention is also characterized in that a lead wiring is formed using the conductive film to achieve connection with other wirings formed on a lower layer.

[0021] According to another structure of the invention disclosed in this specification, there is provided the light emitting device, including:

a pixel portion having a plurality of light emitting elements each including: a first electrode; an organic compound layer formed on the first electrode in contact therewith; and a second electrode formed on the organic compound layer in contact therewith;
a driver circuit; and
a terminal portion,

the device being characterized in that:

in the pixel portion, end portions of the first electrode connected to a thin film transistor are covered with an insulator, the organic compound layer is formed on a part of the insulator and the first electrode, the second electrode is formed on the organic compound layer in contact therewith, and a third electrode made of a conductive material is formed on a region of the second electrode which is not overlapped with the first electrode in contact therewith; and

a portion where a wiring made of a material identical to that of the third electrode or that of the second electrode is connected with a wiring extended from a terminal is formed between the terminal portion and the pixel portion.

[0022] Also, in the above-mentioned structures, the light emitting device is characterized in that the second electrode is a cathode or an anode of the light emitting element.

[0023] Also, in the above-mentioned structures, the light emitting device is characterized in that the third electrode is made of a material having electric resistance lower than that constituting the second electrode and is made of poly-Si doped with an impurity element imparting a conductivity type, an element selected from the group consisting of W, WSi_x, Al, Ti, Mo, Cu, Ta, Cr, and Mo, a film mainly containing an alloy material or a compound material mainly containing the element, or a laminate film thereof. For example, it is preferable that the third electrode is an electrode made of a laminate having a nitride layer or a fluoride layer as an uppermost layer.

[0024] Also, in the above-mentioned structures, the light emitting device is characterized in that the first electrode is a cathode or an anode of the light emitting element. For example, when the second electrode is a cathode, the first electrode serves as an anode, whereas when the second electrode is an anode, the first electrode serves as a cathode.

[0025] Also, in the above-mentioned structures, the light emitting device is characterized in that the insulator is a barrier (also referred to as bank) made of organic resin covered with an inorganic insulating film or is an inorganic insulating film. Note that, the light emitting device is characterized in that the inorganic insulating film is an insulating film mainly containing silicon nitride with a film thickness of 10 to 100 nm.

[0026] Also in the light emitting device, there is a problem in that in a pixel emitting no light, an incident outside light (light outside the light emitting device) is reflected by the rear surface of the cathode (surface brought into contact with an light emitting layer) which acts as mirror and outside scenes are reflected in an observation surface (surface facing an observer side). In order to avoid the problem, the following is devised such that a circular polarization film is attached to the observation surface of the light emitting device to prevent the observation surface from reflecting the outside scenes. However, there arises a problem in that the circular polarization film is extremely expensive, which involves an increase in manufacturing cost.

[0027] Another object of the present invention is to prevent the light emitting device from acting as mirror without using the circular polarization film to accordingly provide an inexpensive light emitting device which attains low manufacturing cost thereof. Accordingly, the present invention is characterized by using an inexpensive color filter instead of using the circular polarization film. In the above-mentioned structure, it is preferable to provide a color filter corresponding to each pixel in the light emitting device in order to increase color purity. Also, a black portion (black organic resin) of the color filter may be arranged so as to overlap each portion between light emitting regions. Further, the black portion (black colored layer) of the color filter may be also arranged so as to overlap a portion where different organic compound layers are partially overlapped with each other.

[0028] Note that, the color filter is provided in an emission direction of an emitted light, i.e., provided between the light emitting element and the observer. For example, when the light is not allowed to pass through the substrate having formed the light emitting element thereon, the color filter may be attached to the sealing substrate. Alternatively, when the light is allowed to pass through the substrate having formed the light emitting element thereon, the color filter may be attached thereto. Thus, it is possible to dispense with the circular polarization film.

[0029] In addition, it is extremely effective that as an anode on a layer containing an organic compound, a transparent conductive film (typically, ITO or ZnO) is used, on which a protective film made of an inorganic insulating film is formed. The following is also effective: as a cathode containing an organic compound, a metal thin film (with a film thickness allowing a light to pass the film) made of Al, Ag, and Mg, or an alloy thereof (typically, AlLi) is used, on which the protective film made of the inorganic insulating film is formed.

[0030] Also, before the protective film made of the inorganic insulating film is formed, it is preferable that a film containing hydrogen, typically a thin film mainly containing carbon, or a silicon nitride film is formed by a plasma CVD method or a sputtering method. Also, the film containing hydrogen may be a laminate film consisting of the thin film mainly containing carbon and the silicon nitride film.

[0031] Further, according to another structure of the present invention, there is provided the light emitting device including a light emitting element over a substrate having an insulating surface, the light emitting element including an anode, a cathode, and an organic compound layer interposed between the anode and the cathode, characterized in that the light emitting element is covered with a film containing hydrogen.

[0032] If heat treatment is performed within a range of temperature to which the organic compound layer can be resistant and heat generated when the light emitting element emits the light is utilized, hydrogen can be diffused from the film containing hydrogen to terminate defects in the organic compound layer with hydrogen (termination). By terminating the defects in the organic compound layer with hydrogen, the light emitting device can be increased in its reliability. Also, when the film containing hydrogen is formed, hydrogen turned into a plasma can be used to terminate defects in the organic compound layer with hydrogen. The protective film formed so as to cover the film containing hydrogen also functions to block hydrogen diffused toward the protective film side and to efficiently diffuse hydrogen into the organic compound layer to terminate defects in the organic compound layer with hydrogen. Further, the film containing hydrogen can serve as the protective film for the light emitting element.

[0033] Further, the film containing hydrogen can serve as a buffer layer. When the silicon nitride film is formed in contact with the transparent conductive film by a sputtering method, there is a possibility that impurities (In, Sn, Zn, etc.) contained in the transparent conductive film are mixed into the silicon nitride film. However, by forming the film containing hydrogen as a buffer layer therebetween, it is also possible to prevent mixture of the impurities into the silicon nitride film. According to the above structure, the buffer layer is formed, so that the impurities (In, Sn, etc.) can be prevented from mixing therein from the transparent conductive film and a superior protective film having no impurities can be formed.

[0034] According to another structure of the present invention, there is provided the light emitting device including a light emitting element over a substrate having an insulating surface, the light emitting element including an anode, a cathode, and an organic compound layer interposed between the anode and the cathode, characterized in that the light emitting element is covered with a film containing hydrogen which is covered with a protective film made of an inorganic insulating film.

[0035] Also, a manufacturing method capable of realizing the above-mentioned structure is included in the present invention. According to a structure relating to a manufacturing method of the present invention, there is provided a manufacturing method for a light emitting device, characterized by including:

> forming a TFT on an insulating surface;
> forming a cathode electrically connected to the TFT;
> forming an organic compound layer on the cathode; and
> forming an anode on the organic compound layer and then forming a film containing hydrogen on the anode.

[0036] Also, according to another structure relating to the manufacturing method of the present invention, there is provided the manufacturing method for a light emitting device, characterized by including:

> forming a TFT on an insulating surface;
> forming an anode electrically connected to the TFT;
> forming an organic compound layer on the anode; and
> forming a cathode on the organic compound layer and then forming a film containing hydrogen on the cathode.

[0037] In the above-mentioned structures relating to the manufacturing method of the present invention, the method is characterized in that the film containing hydrogen is formed by a plasma CVD method or a sputtering method within a range of temperature to which the organic compound layer can be resistant, for example, a range from room temperature to 100°C or less and that the film containing hydrogen is a thin film mainly containing carbon or a silicon nitride film.

[0038] In the above-mentioned structures relating to the manufacturing method of the present invention, the method is characterized in that a step of forming the organic compound layer is performed by an evaporation method, a coating method, an ion plating method, or an ink jet method.

[0039] In the above-mentioned structures relating to the manufacturing method of the present invention, the method is characterized in that a protective film made of an inorganic insulating film is formed on the film containing hydrogen.

[0040] In the above-mentioned structures relating to the manufacturing method of the present invention, the method is characterized in that when the film containing hydrogen is formed, a defect in the organic compound layer is terminated with hydrogen.

[0041] Also, in order to prevent deterioration due to moisture or oxygen, when the light emitting element is sealed with a sealing can or a sealing substrate, a space to be sealed may be filled with a hydrogen gas or with hydrogen and inert gas (rare gas or nitrogen).

[0042] According to another structure of the present invention, there is provided the light emitting device including a light emitting element over a substrate having an insulating surface, the light emitting element including an anode, a cathode, and an organic compound layer interposed between the anode and the cathode, characterized in that the light emitting element is sealed with a substrate having a light-transmissive property and a sealing member, and a sealed space contains hydrogen.

[0043] In the above-mentioned structure, the light emitting device is characterized in that the light emitting element is covered with the film containing hydrogen (thin film mainly containing carbon or silicon nitride film).

[0044] Also, with the above-mentioned structure, heat treatment is performed within a range of temperature to which the organic compound layer can be resistant and heat generated when the light emitting element emits the light is utilized, so that hydrogen can be diffused from the space containing hydrogen to terminate defects in the organic compound layer with hydrogen. By terminating defects in the organic compound layer with hydro-

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