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(54) LASER REPAIRING METHOD OF ELECTROLUMINESCENT DISPLAY DEVICE

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(57) ABSTRACT

The invention is directed to repairing of a defective portion caused by a short circuit without generating a dark spot by a pin hole. Laser beams are irradiated to an irradiating region set in a peripheral region of a foreign substance. This prevents damaging of an organic EL element which the foreign substance adheres to and formation of the pin hole. By irradiating laser beams to the peripheral region at a distance from the foreign substance, energy of the laser beams spreads concentrically around the irradiating region, and is also supplied to the foreign substance indirectly. Therefore, the high resistive region can be formed between an anode layer and a cathode layer so that the defective portion caused by the short circuit by the foreign substance can be repaired.

FIG. 1

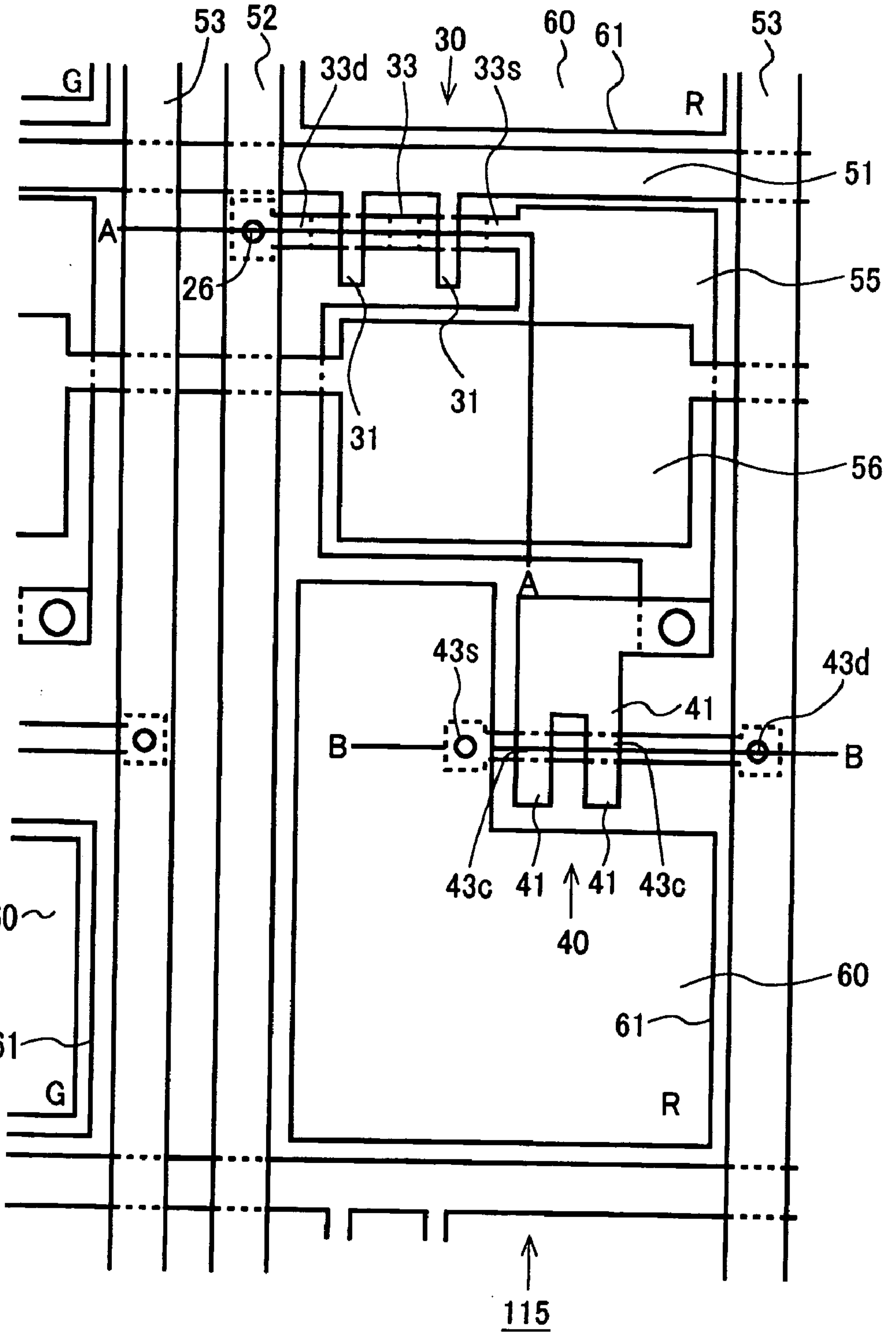

53
52
30
60
61
53
G
33d
33
33s
R
51
A
26
55
31
31
31
56
A
43s
43d
41
B
B
43c
41
41
43c
40
60~
60
61
61
G
R
115

FIG.2A

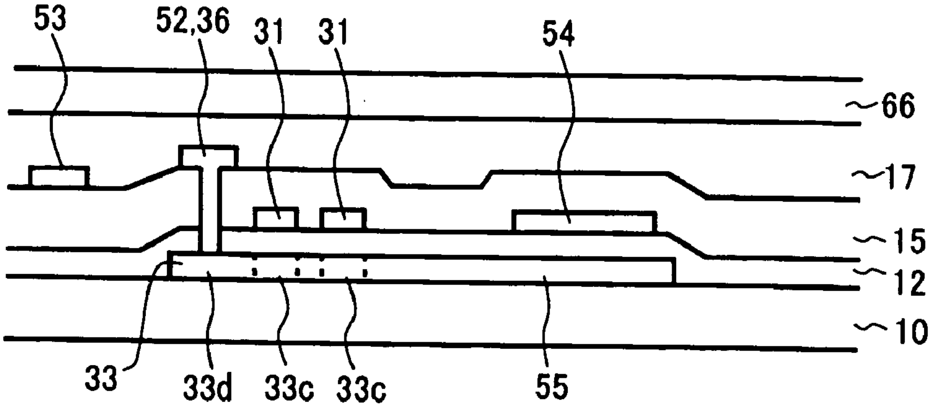

53
52,36
31
31
54
66
17
15
12
10
33
33d
33c
33c
55

FIG.2B

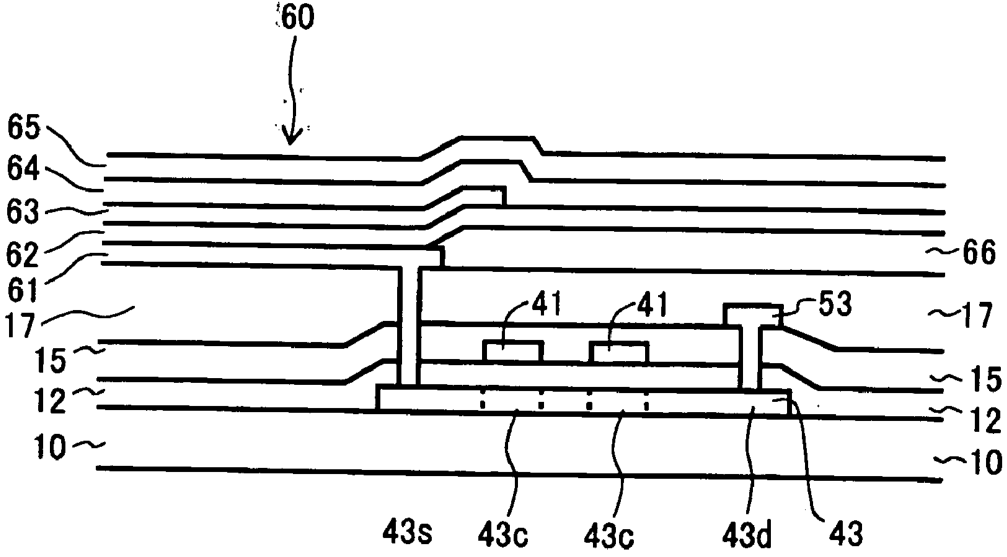

60
65
64
63
62
61
17
15
12
10
41
41
53
66
17
15
12
10
43s
43c
43c
43d
43

FIG.3

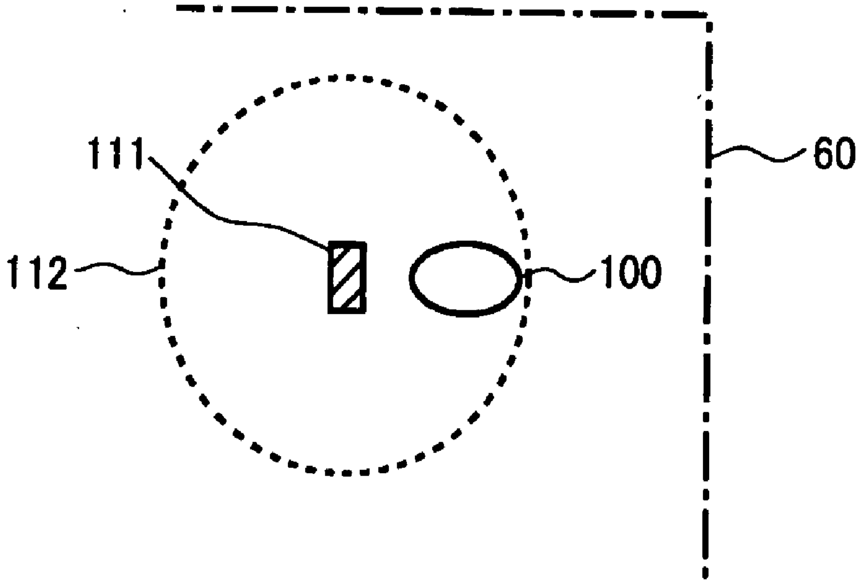


FIG.4

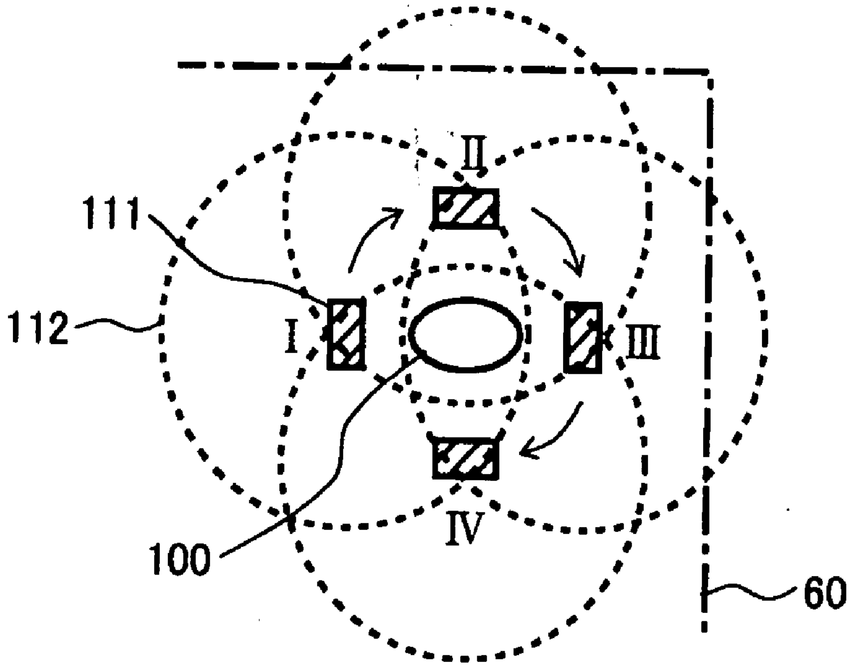


FIG.5

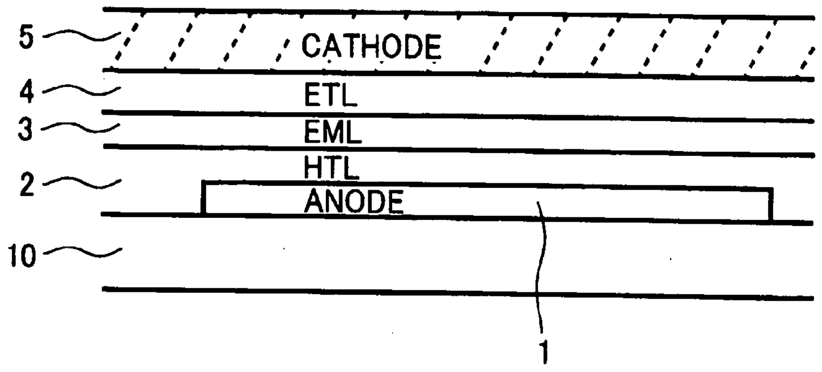
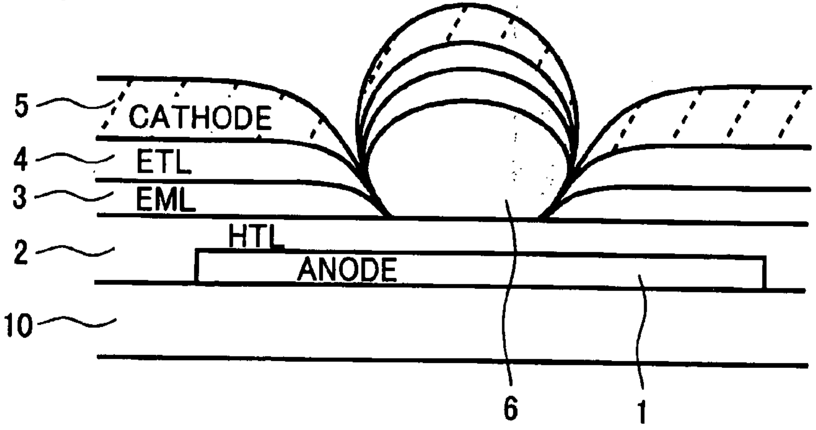

5
CATHODE
4
ETL
3
EML
HTL
2
ANODE
10
1

FIG.6


5
CATHODE
4
ETL
3
EML
HTL
2
ANODE
10
6
1

LASER REPAIRING METHOD OF ELECTROLUMINESCENT DISPLAY DEVICE

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The invention relates to a laser repairing method of an electroluminescent display device having a plurality of pixels and an electroluminescent element provided in each of the pixels and formed by interposing an electroluminescent layer between an anode layer and a cathode layer.

[0003] 2. Description of the Related Art

[0004] An organic electroluminescent (hereafter, referred to as EL) display device using organic EL elements is receiving an attention as a new display device substituted for a CRT or an LCD.

[0005] **FIG. 5** is a cross-sectional view showing a structure of such an organic EL element. An anode layer **1** made of ITO (indium tin oxide) is formed on a transparent insulating substrate **10** such as a glass substrate, and an organic EL layer formed of a hole transport layer **2**, an emissive layer **3**, and an electron transport layer **4** is laminated thereon. A cathode layer **5** is formed on this organic EL layer. A potential difference is applied between the anode layer **1** and the cathode layer **5**. When a drive current flows in the organic EL element, a hole injected from the anode layer **1** and an electron injected from the cathode layer **5** are recombined in the emissive layer **3**, and an organic molecule forming the emissive layer **3** is excited to form an exciton. Light is emitted from the emissive layer **3** in a process of radiation of the exciton and then released outside after going through the transparent anode layer **1** to the transparent insulating substrate **10**, thereby completing light-emission.

[0006] The above organic EL layer and the cathode layer **5** are formed by a vapor deposition method using a metal mask. In this vapor deposition process, a foreign substance **6** sometimes adheres to a region for the formation of the organic EL element. This generates a short circuit between the anode layer **1** and the cathode layer **5** so that a potential difference disappears between the anode layer **1** and the cathode layer **5**. Then, the drive current does not flow in the organic EL element, and a so-called dark spot occurs in this pixel region.

[0007] To solve this problem, laser beams having a predetermined wavelength (for example, 1056 nm) are radiated to the foreign substance **6** to burn it out. This enables normal light-emission at a peripheral pixel region except the pixel irradiated with the laser beams.

[0008] However, when the laser beams are not properly radiated to the foreign substance **6**, the cathode layer **5** is damaged by the energy of the laser beams and can be torn to form a pin hole at the organic EL element. Once the pin hole is formed, moisture enters the organic EL element therefrom to damage the element, resulting in a display defect of a dark spot.

SUMMARY OF THE INVENTION

[0009] The invention provides a method of repairing an electroluminescent display panel using laser. The method includes providing a panel to be assembled into an electroluminescent display device. The panel includes a plurality of pixels each including an electroluminescent element having an electroluminescent layer formed between an anode layer and a cathode layer. The method also includes detecting a foreign substance adhering to the electroluminescent element, and irradiating with a laser beam a region of the display panel that is away from the foreign substance so that a high resistivity region is formed between the anode layer and the cathode layer and around the foreign substance.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] **FIG. 1** is a plan view of an EL display device of an embodiment of the invention.

[0011] **FIGS. 2A and 2B** are cross-sectional views of the EL display device of **FIG. 1**.

[0012] **FIG. 3** is a plan view showing a positioning of a laser beam of a repairing method of the EL display device of **FIG. 1**.

[0013] **FIG. 4** is a plan view showing a multiple positioning of a laser beam of a repairing method of the EL display device of **FIG. 1**.

[0014] **FIG. 5** is a cross-sectional view of a conventional organic EL element.

[0015] **FIG. 6** shows a foreign substance adhering to the organic EL element of **FIG. 5**.

DETAILED DESCRIPTION OF THE INVENTION

[0016] An embodiment of the invention will be described with reference to the drawings in detail. An organic EL display device of this embodiment will be described first. **FIG. 1** is a plan view showing a pixel of the organic EL display device. **FIG. 2A** is a cross-sectional view along line A-A of **FIG. 1**, and **FIG. 2B** is a cross-sectional view along line B-B of **FIG. 1**.

[0017] As shown in **FIGS. 1, 2A**, and 2B, a pixel **115** is formed in a region enclosed with a gate signal line **51** and a drain signal line **52**. A plurality of the pixels **115** is arranged in a matrix configuration.

[0018] An organic EL element **60** as a self-emissive element, a switching TFT (thin film transistor) **30** for controlling a timing of supplying an electric current to the organic EL element **60**, an organic EL element driving TFT **40** for supplying an electric current to the organic EL element **60**, and a storage capacitor **56** are disposed in the pixel **115**.

[0019] The switching TFT **30** is provided on a periphery of the intersection of the signal lines **51** and **52**. A source **33***s* of the switching TFT **30** serves as a capacitor electrode **55** for forming a capacitor with a storage capacitor electrode line **54** and is connected with a gate electrode **41** of the organic EL element driving TFT **40**. A source **43***s* of the organic EL element driving TFT **40** is connected with the anode layer **61** of the organic EL element **60**, while a drain **43***d* is connected with a driving source line **53** as a current source for the organic EL element **60**.

[0020] The storage capacitor electrode line **54** is placed in parallel with the gate signal line **51**. The storage capacitor electrode line **54** is made of Cr (chromium) and so on and forms a capacitor by storing an electric charge with the capacitor electrode **55** connected to the source **33***s* of the TFT **30** through a gate insulating film **12**. The storage capacitor **56** is provided for storing voltage applied to the gate electrode **41** of the organic EL element driving TFT **40**.

[0021] The organic EL display device is formed by laminating the TFTs and the organic EL element sequentially on a substrate **10**, such as a substrate made of a glass or a synthetic resin, a substrate having conductivity, or a semiconductor substrate. When using a substrate having conductivity or a semiconductor substrate as the substrate **10**, however, an insulating film made of SiO_2 or SiN_x is formed on the substrate **10**, and then the switching TFT **30**, the organic EL element driving TFT **40** and the organic EL element **60** are formed thereon. Each of the TFTs **30** and **40** has a so-called top gate structure in which a gate electrode is placed above an active layer with a gate insulating film being interposed therebetween.

[0022] The structure of the switching TFT **30** will be described first.

[0023] As shown in **FIG. 2A**, an amorphous silicon film (hereafter, referred to as an a-Si film) is formed on the insulating substrate **10** made of silica glass or a non-alkali glass by a CVD method and so on. The a-Si film is irradiated with laser beams for melting and recrystalizing to form a poly-silicon film (hereafter, referred to as a p-Si film) as an active layer **33**. On the active layer **33**, a single-layer or a multi-layer having an SiO_2 film and an SiN_x film is formed as the gate insulating film **12**. There are formed on the gate insulating film **12** the gate signal line **51** made of a metal having a high melting point, such as Cr or Mo (molybdenum), and also serving as a gate electrode **31**, the drain signal line **52** made of Al (aluminum), and the driving source line **53** made of Al and serving as a driving source of the organic EL element **60**.

[0024] An interlayer insulating film **15** formed by laminating an SiO_2 film, an SiN_x film and an SiO_2 film covers the whole surfaces of the gate insulating film **12** and the active layer **33**. A drain electrode **36** is provided by filling a contact hole provided above the drain **33***d* with a metal such as Al. Furthermore, a first planarization insulating film **17** for planarizing a surface, which is made of an organic resin, is formed on the whole surface.

[0025] Next, the structure of the organic EL element driving TFT **40** will be described. As shown in **FIG. 2B**, an active layer **43** formed by poly-crystalizing an a-Si film by irradiating the film by laser beams, the gate insulating film **12**, and the gate electrode **41** made of a metal having a high melting point, such as Cr or Mo, are formed sequentially on the insulating substrate **10** made of silica glass, or a non-alkali glass. A channel **43***c*, a source **43***s*, and a drain **43***d* are provided in the active layer **43**. The source **43***s* and the drain **43***d* are placed on both sides of the channel **43***c*.

[0026] The interlayer insulating film **15** having the SiO_2 film, the SiN_x film and the SiO_2 film is formed on the whole surfaces of the gate insulating film **12** and the active layer **43**. The driving source line **53** is connected to a driving source by a contact hole filled with a metal such as Al provided on the drain **43***d*. Furthermore, a planarization insulating film **17** for planarizing the surface, which is made of, for example, an organic resin is formed on the whole surface. A contact hole is formed in a position corresponding to a source **43***s* in the planarization insulating film **17**. A transparent electrode made of ITO and being in contact with the source **43***s* through the contact hole, i.e., the anode layer **61** of the organic EL element, is formed on the planarization insulating film **17**. The anode layer **61** is formed in each of the pixels as an isolated island.

[0027] The organic EL element **60** has a structure of laminating sequentially the anode layer **61** made of a transparent electrode such as ITO, a hole transport layer **62** including a first hole transport layer made of MTDATA (4,4-bis(3-methylphenylphenylamino) biphenyl) and a second hole transport layer made of TPD (4,4,4-tris(3-methylphenylphenylamino)triphenylanine), an emissive layer **63** made of Bebq2 (bis(10-hydroxybenzo[h]quinolinato)beryllium) containing a quinacridone derivative, an electron transport layer **64** made of Bebq2 and a cathode layer **65** made of magnesium-indium alloy, Al or Al alloy.

[0028] A second planarization insulating film **66** is formed on the planarization insulating film **17**. This second planarization insulating film **66** is patterned to expose the anode layer **61**.

[0029] In the organic EL element **60**, a hole injected from the anode layer **61** and an electron injected from the cathode layer **65** are recombined in the emissive layer **63**, and an exciton is formed by exciting an organic module forming the emissive layer **63**. Light is emitted from the emissive layer **63** in a process of radiation of the exciton and then released outside after going through the transparent anode layer **61** to the transparent insulating substrate **10**, thereby completing light-emission.

[0030] Next, a laser repairing method of the above described organic EL display device will be described. As shown in **FIG. 3**, a foreign substance **100** is now detected adhering to the organic EL element **60** of one pixel. A cross-section of the structure shown in **FIG. 3** is similar to that shown in **FIG. 6**. As a method of detecting a foreign substance, for example, visual observation using a microscope or an automatic detecting method by a foreign substance detecting device can be employed.

[0031] In the repairing method of this embodiment, laser beams are configured not to directly incident on the foreign substance **100**, but to be incident on an irradiation region **111** near the foreign substance **100**. This prevents the organic EL element **60** having the foreign substance **100** from being damaged and thus prevents a pin hole formation. By irradiating with the laser beams the irradiation region **111** at a predetermined distance from the foreign substance **100**, the energy of the laser beams spreads concentrically from the irradiating region **111**, i.e., the laser beams do not hit the foreign substance **100** directly. Accordingly, the laser energy is supplied to the foreign substance **100** indirectly. This spread of the laser energy forms a high resistivity region **1112**, shown in **FIG. 3**, between the anode layer **61** and the cathode layer **65** so that a defective portion caused by a short circuit by the foreign substance **100** can be repaired. This high resistivity region **112** is formed because the hole transport layer **2**, the emissive layer **3** and the electron transport layer **4** in this region **112** are melted together by thermal energy of the laser beams and thus the layered structure thereof disappears.

[0032] Here, a commercially available YAG laser (for example, having a laser wavelength of 355 nm) can be used as the laser source. The size of the irradiating region **111** is 5 μm by 5 μm, for example. The size of the foreign substance **100** is 0.3 μm to 10 μm. It is preferable to set the irradiation region **111** at a distance of 5 μm to 10 μm from the foreign substance **100**.

[0033] When the size of the foreign substance **100** is 3 μm or more, it is preferable to supply a large amount of energy to the irradiation region **111** by positioning the laser beams to four different peripheral regions of the foreign substance **100**, that is, a left side, an upper side, a right side and a lower side (I to IV in **FIG. 4**) of the foreign substance **100**, as shown in **FIG. 4**. The number of the multiple irradiation can be increased or decreased as appropriate based on the size of the foreign substance **100**.

[0034] In this embodiment, the laser beams having a wavelength of 532 nm or lower can repair the defective portion without damaging the organic EL element.

What is claimed is:

1. A method of repairing an electroluminescent display panel using laser, comprising:

providing a panel to be assembled into an electroluminescent display device, the panel comprising a plurality of pixels each including an electroluminescent element having an electroluminescent layer formed between an anode layer and a cathode layer;

detecting a foreign substance adhering to the electroluminescent element; and

irradiating with a laser beam a region of the display panel that is away from the foreign substance so that a high resistivity region is formed between the anode layer and the cathode layer and around the foreign substance.

2. The method of claim 1, wherein the laser beam irradiation is repeated a plurality of times so that a plurality regions of the display panel around the foreign substance is irradiated.

3. The method of claim 1, wherein a wavelength of the laser beam is 532 nm or lower.

4. The method of claim 2, wherein a wavelength of the laser beam is 532 nm or lower.

5. The method of claim 1, wherein the irradiated region of the display panel is away from the foreign substance by a distance between 5 μm and 10 μm.

6. The method of claim 2, wherein the irradiated region of the display panel is away from the foreign substance by a distance between 5 μm and 10 μm.

* * * * *

专利名称(译)	电致发光显示装置的激光修复方法		
公开(公告)号	US20040202777A1	公开(公告)日	2004-10-14
申请号	US10/758598	申请日	2004-01-16
[标]申请(专利权)人(译)	三洋电机株式会社		
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[标]发明人	NISHIKAWA RYUJI NAGATA RYOZO OGAWA TAKASHI		
发明人	NISHIKAWA, RYUJI NAGATA, RYOZO OGAWA, TAKASHI		
IPC分类号	H05B33/10 G09G3/00 H01L27/32 H01L51/50 H01L51/56		
CPC分类号	G09G3/006 H01L2251/568 H01L51/56		
优先权	2003012381 2003-01-21 JP		
其他公开文献	US7611745		
外部链接	Espacenet USPTO		

摘要(译)

本发明旨在修复由短路引起的缺陷部分，而不会由针孔产生暗点。激光束照射到设置在外来物质的周边区域中的照射区域。这防止了异物附着的有机EL元件的损坏和针孔的形成。通过将激光束照射到与外来物质相距一定距离的周边区域，激光束的能量在照射区域周围同心地扩散，并且也间接地供给到外来物质。因此，可以在阳极层和阴极层之间形成高电阻区域，从而可以修复由异物引起的短路引起的缺陷部分。

FIG. 1