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(54) **ORGANIC LIGHT EMITTING DIODE DISPLAY AND MANUFACTURING METHOD THEREOF**

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CPC ***H01L 51/5256*** (2013.01); ***H01L 51/5268*** (2013.01)

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USPC 438/22, 26, 28, 38, 99, 623, 780–781, 438/789–790, 793–794; 257/40, 642, 759, 257/E23.107, E21.292, E51.001, E51.018, 257/E51.02, E51.002, E51.021, E51.022, 257/E51.038
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,038,008 A * 3/2000 Kim et al. 349/138
6,413,645 B1 7/2002 Graff et al.

(Continued)

FOREIGN PATENT DOCUMENTS

JP 2007-073355 3/2007
KR 10-2002-0080067 10/2002

(Continued)

OTHER PUBLICATIONS

"Which Fractal Parameter Contributes Most to Adhesion?," D.-L. Liu, J. Martin and N. A. Burnham, a Department of Physics, Worcester Polytechnic Institute, Worcester, MA, USA, Adhesion Aspects in MEMS/NEMS (2010) 45-58).*

(Continued)

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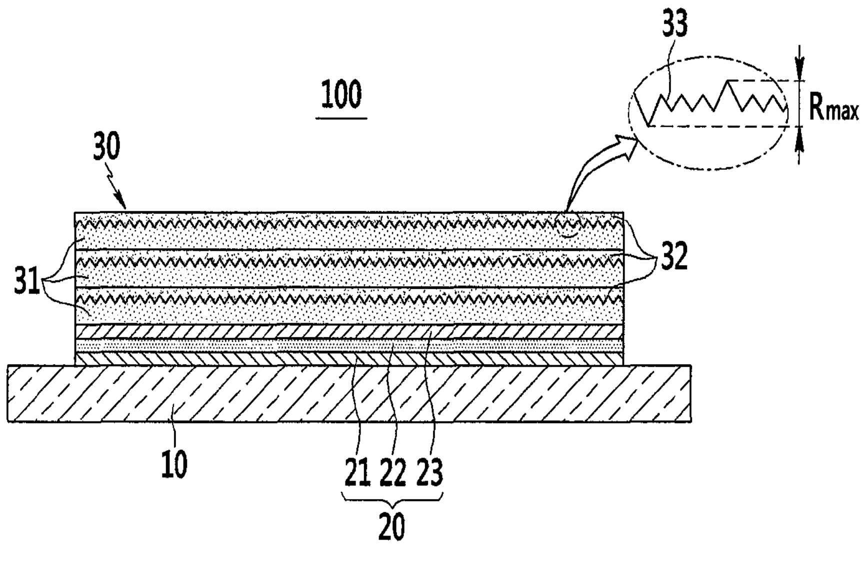
(57) **ABSTRACT**

An OLED display includes: a substrate; an organic light emitting element formed on the substrate and including a first electrode, an emission layer, and a second electrode; and an encapsulation layer formed on the substrate while covering the organic light emitting element. The encapsulation layer includes an organic layer and an inorganic layer, and a protrusion and depression structure is formed in an interface between the organic layer and the inorganic layer.

7 Claims, 6 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

6,969,634	B2*	11/2005	Bao	438/99
7,133,100	B2*	11/2006	Ahn	349/138
7,205,565	B2*	4/2007	Im et al.	257/40
7,473,932	B2*	1/2009	Cho et al.	257/88
7,906,898	B2*	3/2011	Lee	313/504
8,168,984	B2*	5/2012	Lin et al.	257/76
8,455,282	B2*	6/2013	Kim et al.	438/42
8,569,951	B2	10/2013	Ryu et al.	
2004/0263740	A1*	12/2004	Sakakura et al.	349/138
2005/0026454	A1*	2/2005	Konishi et al.	438/778
2005/0175831	A1*	8/2005	Kim	B32B 33/00 428/323
2007/0159094	A1*	7/2007	Oh et al.	313/512
2007/0166851	A1*	7/2007	Tran et al.	438/22
2007/0290607	A1*	12/2007	Okada et al.	313/504
2007/0291200	A1*	12/2007	Tashiro et al.	349/112
2008/0157065	A1*	7/2008	Krishnamoorthy et al.	257/40
2008/0305360	A1*	12/2008	Han et al.	428/690
2009/0137178	A1*	5/2009	Sakakura et al.	445/25
2009/0202743	A1*	8/2009	Schaepkens et al.	427/576
2010/0136728	A1*	6/2010	Horng et al.	438/29
2010/0320909	A1*	12/2010	Izumi	315/51
2011/0114931	A1*	5/2011	Lee et al.	257/40
2011/0121355	A1*	5/2011	Bae et al.	257/100
2011/0121469	A1*	5/2011	Blander et al.	257/788
2011/0171764	A1	7/2011	Toonen et al.	
2011/0175073	A1*	7/2011	Chang	257/40
2011/0272682	A1*	11/2011	Blizzard et al.	257/40
2011/0277653	A1*	11/2011	Nguyen	101/453
2012/0139000	A1*	6/2012	Lee et al.	257/99
2012/0155093	A1*	6/2012	Yamada et al.	362/311.01
2012/0199872	A1	8/2012	Chen et al.	
2012/0208306	A1	8/2012	Haas et al.	
2012/0256202	A1*	10/2012	Lee et al.	257/88
2012/0286245	A1*	11/2012	Levermore et al.	257/40
2012/0326131	A1	12/2012	Han	
2012/0326192	A1*	12/2012	Van Slyke et al.	257/98
2013/0175710	A1*	7/2013	Sakakura et al.	257/787
2013/0210199	A1*	8/2013	Chen	C23C 16/26 438/127
2013/0244079	A1*	9/2013	Mandlik et al.	429/122
2013/0334511	A1*	12/2013	Savas	H01L 51/56 257/40
2014/0087162	A1*	3/2014	Ma	B32B 27/28 428/216
2015/0054422	A1*	2/2015	Koo	H04B 33/0872 315/250

FOREIGN PATENT DOCUMENTS

KR	10-2005-0048133	A	5/2005
KR	10-2005-0117255	A	12/2005
KR	10-2006-0031487		4/2006
KR	10-2008-0087257	A	10/2008
KR	10-2010-0027902	A	3/2010

OTHER PUBLICATIONS

U.S. Notice of Allowance dated Oct. 27, 2014, for cross reference U.S. Appl. No. 13/298,118, (7 pages).

* cited by examiner

FIG. 1

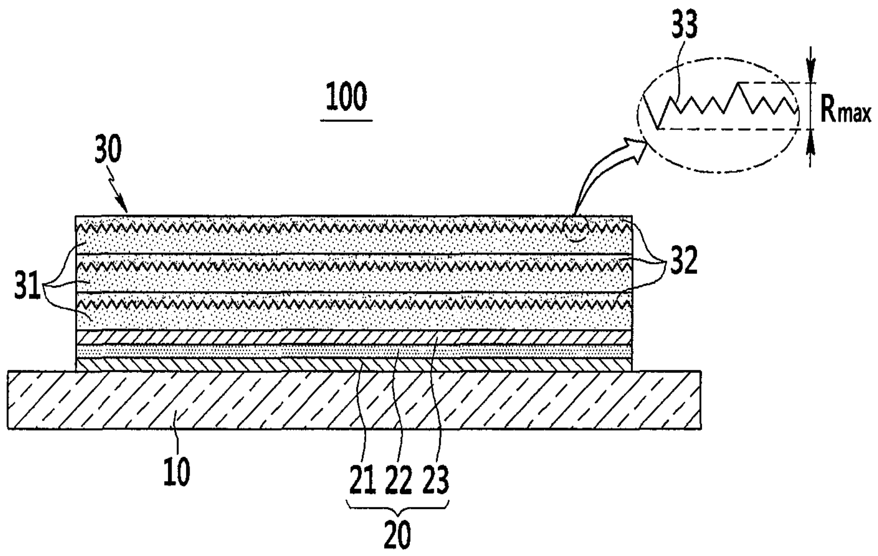


FIG. 2

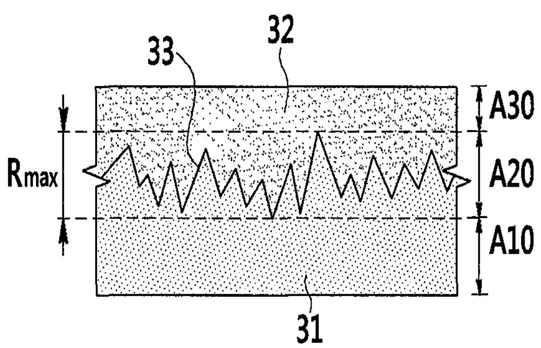


FIG. 3A

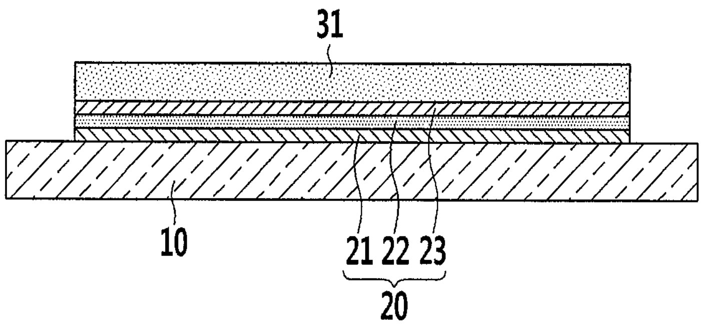


FIG. 3B

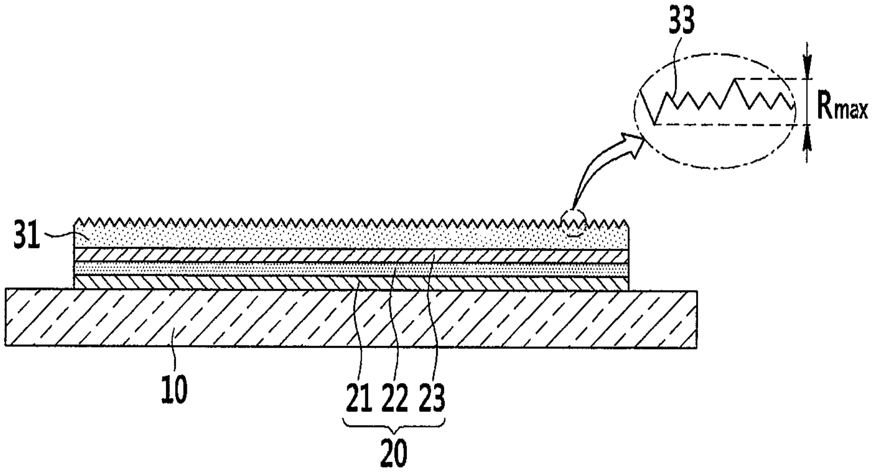


FIG. 3C

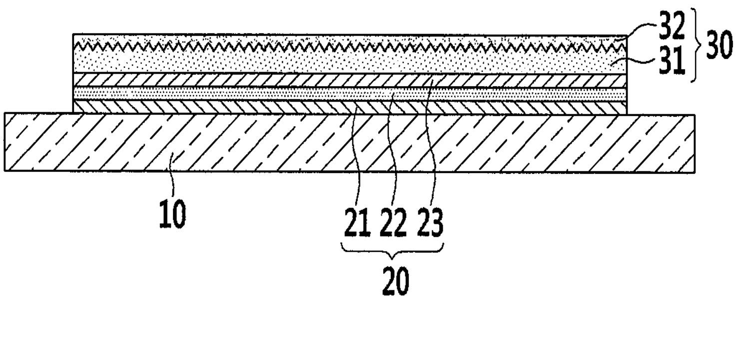


FIG. 4

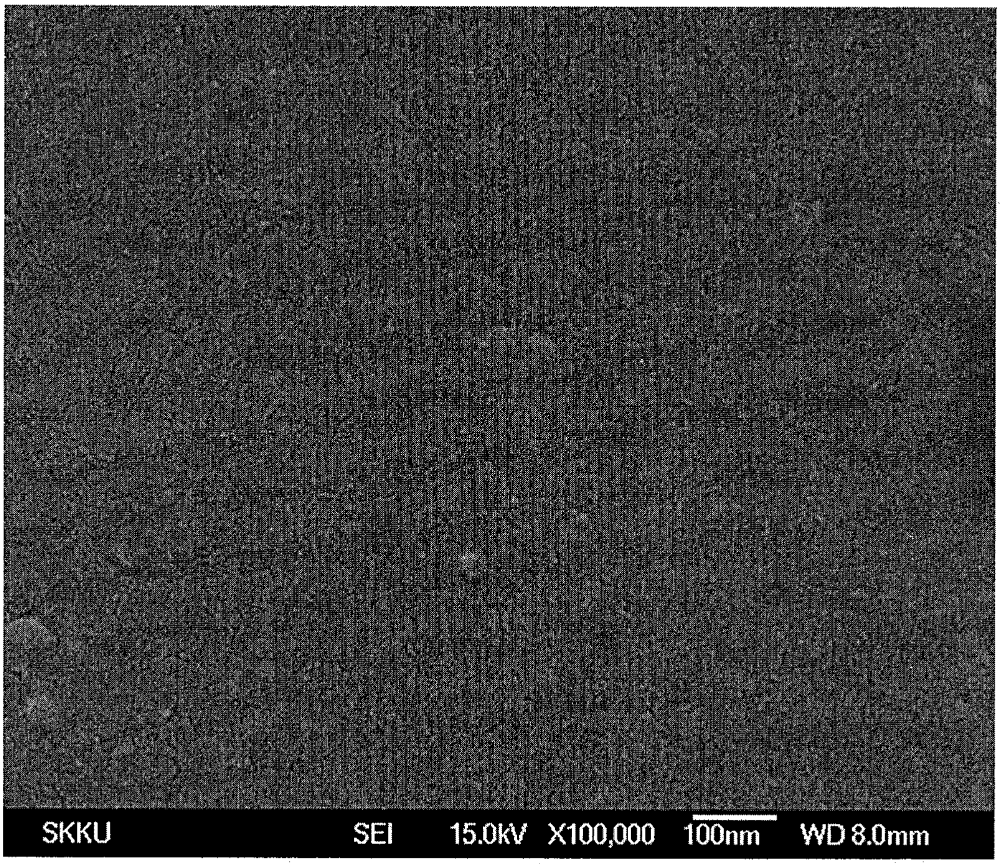


FIG. 5

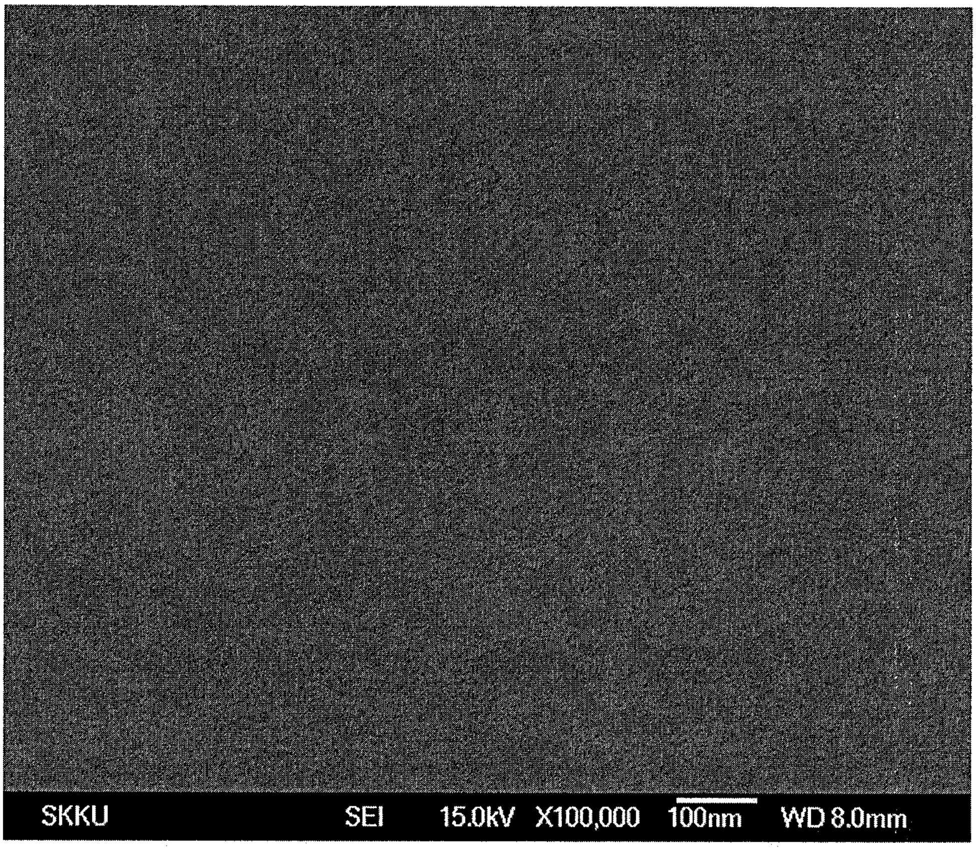


FIG. 6

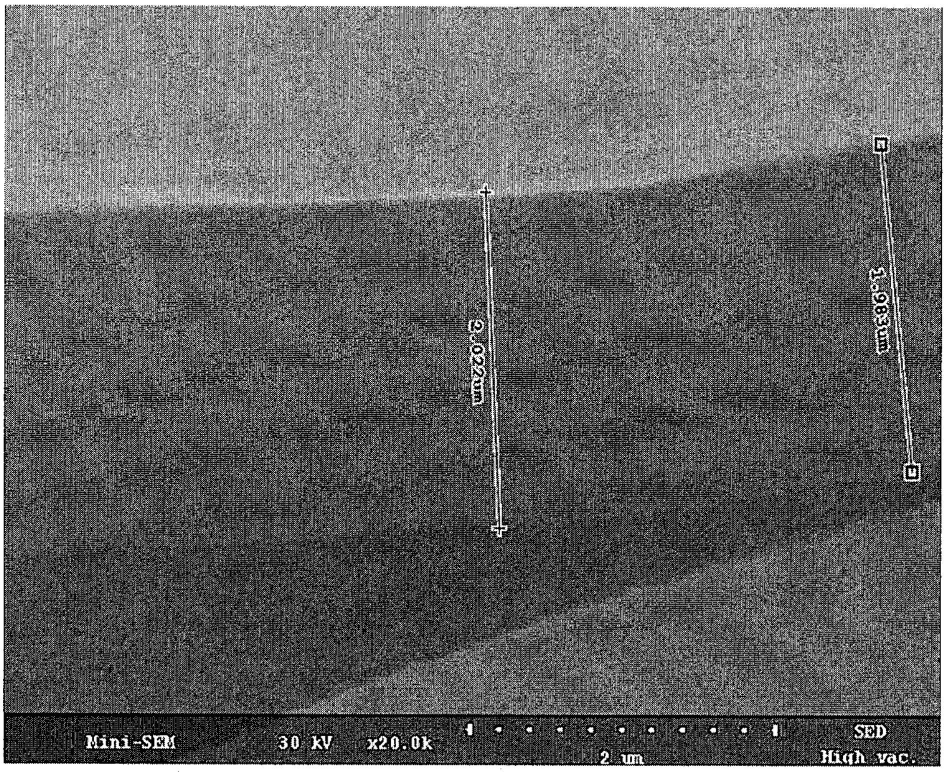


FIG. 7

ORGANIC LIGHT EMITTING DIODE DISPLAY AND MANUFACTURING METHOD THEREOF

CROSS-REFERENCE TO RELATED APPLICATION

This application claims priority to and the benefit of Korean Patent Application No. 10-2011-0031322, filed in the Korean Intellectual Property Office on Apr. 5, 2011, the entire content of which is incorporated herein by reference.

BACKGROUND

1. Field

The described technology relates generally to an organic light emitting diode (OLED) display. More particularly, the described technology relates generally to an OLED display having an encapsulation layer to protect an organic light emitting element from external moisture and oxygen, and a manufacturing method thereof.

2. Description of Related Art

Organic light emitting diode displays are typical displays that emit light by themselves and have small thickness and weight, because they do not need independent light sources, and also have excellent or desired characteristics, such as small power consumption, high luminance, and high response speed.

A plurality of organic light emitting elements, each formed of a first electrode, a second electrode, and a light emission layer disposed between the first and second electrodes, are disposed in a display portion of the OLED display. Since a display function and a life-span characteristic are deteriorated when the organic light emitting element is exposed to external moisture and oxygen, an encapsulation layer is formed on the display portion to seal the display portion. The encapsulation layer may have a multilayer structure formed by alternatively layering organic layers and inorganic layers several times.

The above information disclosed in this Background section is only for enhancement of understanding of the background of the described technology and therefore it may contain information that does not form the prior art that is already known in this country to a person of ordinary skill in the art.

SUMMARY

The described technology is directed toward an effort to provide an organic light emitting diode (OLED) display with an encapsulation layer having an improved sealing function by improving structures of organic and inorganic layers forming the encapsulation layer, and a manufacturing method thereof.

An OLED display according to an exemplary embodiment includes: a substrate; an organic light emitting element formed on the substrate and including a first electrode, an emission layer, and a second electrode; and an encapsulation layer formed on the substrate while covering the organic light emitting element. The encapsulation layer includes an organic layer and an inorganic layer, and a protrusion and depression structure is formed in an interface between the organic layer and the inorganic layer.

The protrusion and depression structure may have a root mean square (RMS) roughness in a range between 30 Å to 100 nm. The surface roughness of the protrusion and depression structure may have a maximum height (Rmax) in a range between 50 Å to 200 nm.

The protrusion and depression structure may be formed in a surface of the organic layer, and the inorganic layer may be formed on the organic layer. The surface roughness of the protrusion and depression structure may include a root mean square (RMS) roughness in a range between 30 Å to 100 nm and a maximum height (Rmax) in a range between 50 Å to 200 nm.

The organic layer and the inorganic layer may be respectively provided in plural, and the protrusion and depression structure may be formed at each interface where the inorganic layer is layered on the organic layer.

The organic layer may include at least one material selected from a group consisting of a carbide-based material, a carbonate-based material, an acryl-based resin, a methacryl-based resin, polyisoprene, a vinyl-based resin, an epoxy-based resin, a urethane-based resin, a cellulous-based resin, and a perylene-based resin.

The inorganic layer may include at least one material selected from a group consisting of silicon nitride, aluminum nitride, zirconium nitride, titanium nitride, hafnium nitride, tantalum nitride, silicon oxide, aluminum oxide, titanium oxide, tin oxide, cerium oxide, and silicon oxynitride.

A manufacturing method of an OLED display according to another exemplary embodiment includes: forming an organic light emitting element to include a first electrode, an emission layer, and a second electrode on a substrate and forming an encapsulation layer on the organic light emitting element. The forming of the encapsulation layer includes forming an organic layer, forming a protrusion and depression structure in a surface of the organic layer by dry-etching the surface of the organic layer, and forming an inorganic layer on the organic layer where the protrusion and depression structure is formed.

The protrusion and depression structure may have a root mean square (RMS) roughness in a range between 30 Å to 100 nm and a surface roughness maximum height (Rmax) in a range between 50 Å to 200 nm.

In the dry-etching process, at least one gas selected from a group consisting of SiF_4, CF_4, C_3F_8, C_2F_6, CHF_3, $CClF_3$, O_2, NF_3, and SF_6 may be used as a process gas.

The organic layer may be formed utilizing a deposition method in a chamber of the PECVD equipment, and the dry-etching may be continuously performed in the chamber after the organic layer is formed.

The dry-etching may be performed in the plasma etching equipment, and one of ion-beam etching, inductively coupled plasma etching, and reactivity ion etching may be employed for the dry-etching. Also, a radio frequency power in a range between 10 mW to 2,000 W and a process pressure in a range between 0.1 torr to 10 torr may be applied for the dry-etching process.

The OLED display can prevent a layer fall-off phenomenon by enhancing a bonding force between an organic layer and an inorganic layer that form an encapsulation, and can improve a sealing function of the encapsulation by suppressing penetration of external moisture and oxygen along an interface between the organic and inorganic layers. Further, the OLED display can enhance light extraction efficiency by reducing internal reflection in the interface between the organic and inorganic layers.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematically cross-sectional view of an OLED display according to an exemplary embodiment.

FIG. **2** is a partially enlarged view of an encapsulation layer of FIG. **1**.

FIG. 3A to FIG. 3C are schematically cross-sectional views for describing a manufacturing method of an OLED display according to an exemplary embodiment.

FIG. 4 is an SEM photo of a surface of an organic layer according to an exemplary embodiment processed through a step shown in FIG. 3B.

FIG. 5 is an SEM photo of a surface of an organic layer according to a comparative example that is not plasma etched.

FIG. 6 is an SEM photo of a cross-section of the encapsulation layer according to the present exemplary embodiment.

FIG. 7 is an SEM photo of a cross-section of an encapsulation layer according to a comparative example.

DETAILED DESCRIPTION

The present invention will be described more fully hereinafter with reference to the accompanying drawings, in which exemplary embodiments of the invention are shown. As those skilled in the art would realize, the described embodiments may be modified in various different ways, all without departing from the spirit or scope of the present invention.

In the drawings, the thickness of layers, films, regions, etc., are exaggerated for clarity. It will be understood that when an element such as a layer, film, region, or substrate is referred to as being "on" another element, it can be directly on the other element or one or more intervening elements may also be present therebetween. By contrast, it will be understood that when an element is referred to as being "directly on" another element, intervening elements are not present.

FIG. 1 is a schematically cross-sectional view of an organic light emitting diode (OLED) display according to an exemplary embodiment, and FIG. 2 is a partially enlarged view of an encapsulation layer of FIG. 1.

Referring to FIG. 1 and FIG. 2, an OLED display **100** includes a substrate **10**, an organic light emitting element **20** formed on the substrate **10**, and an encapsulation layer **30** formed on the substrate **10** while covering the organic light emitting element **20**. The organic light emitting element **20** includes a first electrode **21**, an emission layer **22**, and a second electrode **23**. The encapsulation layer **30** includes an organic layer **31** and an inorganic layer **32**, and a protrusion and depression structure **33** (having protrusions and depressions) is formed at a boundary between the organic layer **31** and the inorganic layer **32**.

The substrate **10** may be a glass substrate or a plastic substrate. The substrate **10** may be formed with a glass or plastic material having excellent, desired or suitable mechanical strength, thermal stability, transparency, surface flatness, and water resistance. A barrier layer that blocks penetration of moisture and oxygen may also be disposed on the substrate **10**. The barrier layer may be formed of one inorganic layer and one organic layer or formed by multiple layerings of the inorganic layers and the organic layers.

The organic light emitting element **20** is disposed on the substrate **10**. The organic light emitting element **20** has a structure in which the first electrode **21**, the emission layer **22**, and the second electrode **23** are layered. One of the first electrode **21** and the second electrode **23** functions as a hole injection electrode and the other functions as an electron injection electrode.

The first electrode **21** and the second electrode **23** may be a transparent electrode, a partially transparent electrode, or a reflective electrode. When the first electrode **21** is a transparent electrode and the second electrode **23** is a reflective electrode, light from the emission layer **22** is reflected by the second electrode **23** and emitted to the outside after passing through the first electrode **21** and the substrate **10**. On the contrary, when the first electrode **21** is a reflective electrode and the second electrode **23** is a transparent electrode, light from the emission layer **22** is reflected by the first electrode **21** and emitted to the outside after passing through the second electrode **23** and the encapsulation layer **30**.

In addition to the emission layer **22**, at least one of a hole injection layer (HIL), a hole transport layer (HTL), an electron transport layer (ETL), and an electron injection layer (EIL) may be further formed between the first and second electrodes **21** and **23**. When a driving voltage is applied to the first electrode **21** and the second electrode **23**, electrons and holes are injected to the emission layer **22** and exitons are generated from combination of the injected electrons and holes, and light is emitted when the excitons drop from the excited stated to the ground state.

The organic light emitting elements are disposed in a display portion of the substrate **10**. Each of the organic light emitting elements is connected to a driving circuit including a thin film transistor such that light emission of the organic light emitting element is controlled by the driving circuit. In FIG. 1, the driving circuit is omitted for convenience driving circuit description, and one organic light emitting element is illustrated instead of illustrating the plurality of organic light emitting elements.

The encapsulation layer **30** protects the organic light emitting element **20** from external moisture and oxygen by sealing the organic light emitting element **20**. The encapsulation layer **30** includes a plurality of organic layers **31** and a plurality of inorganic layers **32**, and is formed by alternately layering the respective organic layers **31** and the respective inorganic layers **32**. In general, the inorganic layers **32** suppress penetration of moisture and oxygen, and the organic layers fill micro cracks and pin holes.

An interface of the organic layer **31** and the inorganic layer **32** is provided in plural in the encapsulation layer **30**. A protrusion and depression structure **33** (having protrusions and depressions) is formed in one of the plurality of interfaces. The protrusion and depression structure **33** has an irregular pattern rather than having a concave groove or a protrusion formed in a predetermined shape. The protrusion and depression structure **33** may be formed by employing a dry etching method.

The protrusion and depression structure **33** has a root mean square (RMS) roughness in a range between 30 Å to 100 nm or a surface roughness having the maximum height (Rmax) that is in a range between 50 Å to 200 nm. The RMS roughness refers to a roughness value acquired by using an RMS method generally used in the field of statistics, and the maximum height (Rmax) refers to a vertical distance between the highest peak and the lowest hollow of the protrusion and depression structure **33**.

The protrusion and depression structure **33** may be formed in a surface of the organic layer **31**. That is, the organic layer **31** is formed using a heat treatment or deposition method after coating, and then the surface roughness of the organic layer **31** may be increased by dry etching the surface of the organic layer **31**.

In addition, an inorganic layer **32** is formed by depositing an inorganic material on the organic layer **31** to fill gaps between the hollows of the protrusion and depression structure **33**. As described, wettability of the inorganic layer **32** with respect to the organic layer **31** is enhanced by the protrusion and depression structure **33** so that the inorganic layer **32** can be further robustly attached on the organic layer **31**. Since the organic layer **31** and the inorganic layer **32** contact each other, interposing a rough interface therebetween, no definite interface is observed between the organic layer **31** and the inorganic layer **32**.

In observation of a cross-section of the encapsulation layer **30**, the encapsulation layer **30** is divided into an organic material area A**10** formed of only an organic material, a mixed area A**20** where the organic material and an inorganic material co-exist, and an inorganic material area A**30** formed of only an inorganic material. The organic material area A**10**, the mixed area A**20**, and the inorganic material area A**30** are arranged along a thickness direction (vertical direction of FIG. **2**) of the encapsulation layer **30**. The thickness of the mixed area A**20** is equivalent to (or the same as) the surface roughness maximum height (Rmax) of the protrusion and depression structure **33**.

When the organic layer is formed and the inorganic layer is formed on the organic layer without performing surface treatment, the organic layer and the inorganic layer have a definite interface between the organic layer and the inorganic layer and thus they may be separated from each other, thereby causing a layer falling-off phenomenon. In addition, moisture and oxygen included in the external air penetrate into the encapsulation layer along the interface between the organic layer and the inorganic layer such that the sealing function of the encapsulation layer is deteriorated. In this case, the encapsulation layer has excellent sealing effect along the thickness direction thereof, but the sealing effect is decreased along a plane direction of the encapsulation layer. In this case, the plane direction implies a direction that is parallel with the organic layer or the surface of the organic layer.

However, in the present exemplary embodiment, the adherence between the organic layer **31** and the inorganic layer **32** is improved by the protrusion and depression structure **33** such that the layer falling-off phenomenon can be prevented or reduced. In addition, since the protrusion and depression structure **33** functions to block the penetration of moisture and oxygen, the sealing effect of the encapsulation layer **30** along the plane direction thereof is enhanced, thereby improving the sealing performance. That is, in the present exemplary embodiment, the sealing performance of the encapsulation layer **30** can be excellently realized along the thickness and plane directions.

As previously described, the protrusion and depression structure **33** may have root mean square (RMS) roughness in a range between 30 Å to 100 nm or surface roughness having the maximum height (Rmax) that is in a range between 50 Å to 200 nm.

In one embodiment, when the RMA roughness of the protrusion and depression structure **33** is less than 30 Å or the maximum height (Rmax) is less than 50 Å, the adherence between the organic layer **31** and the inorganic layer **32** is not strong enough to prevent the layer falling-off phenomenon and the sealing function of the encapsulation layer **30** is deteriorated along the plane direction. In another embodiment, when the RMS roughness of the protrusion and depression structure **33** exceeds 100 nm or the maximum height (Rmax) exceeds 200 nm, the organic layer **31** is over-etched so that a driving characteristic of the organic light emitting element **20** is deteriorated, and an additional process (e.g., photolithography, etc.) for easing the excessive roughness is required, thereby causing the process to be complicated.

Further, the organic layer **31** and the inorganic layer **32** cause a refractive index to be changed due to the protrusion and depression structure **33** such that light efficiency can be improved. In case of a front emission type OLED display, when the light from the emission layer **22** passes through the encapsulation layer **30**, internal reflection at the rough interface of the organic and inorganic layers **31** and **32** can be reduced so that the light extraction efficiency can be improved. Further, when external light is incident on the encapsulation layer, reflection of the external light can be suppressed by refracting the external light at the rough interface between the organic layer **31** and the inorganic layer **32**. The light extraction efficiency refers to luminance improvement of the screen, and the suppression of reflection of the external light improves contrast of the screen.

The organic layer **31** has a refractive index in a range between 1.2 to 2.0, and the inorganic layer **32** has a refractive index in a range between 1.3 to 2.2. A refractive index difference between the organic layer **31** and the inorganic layer **32** is set to be higher than 0.1 to improve light extraction efficiency, and the light extraction efficiency can be increased as the refractive index difference between the organic and inorganic layers **31** and **32** is increased.

The organic layer **31** may include at least one of a carbide-based material, a carbonate-based material, an acryl-based resin, a methacryl-based resin, polyisoprene, a vinyl-based resin, an epoxy-based resin, a urethane-based resin, a cellulous-based resin, and a perylene-based resin. The plurality of organic layers **31** may include the same material or different materials. The organic layer **31** may have a rough surface through a plasma etching process. The plasma etching process will be described later in further detail.

The inorganic layer **32** may include at least one of silicon nitride, aluminum nitride, zirconium nitride, titanium nitride, hafnium nitride, tantalum nitride, silicon oxide, aluminum oxide, titanium oxide, tin oxide, cerium oxide, and silicon oxynitride. The plurality of inorganic layers **32** may include the same material or different materials.

FIG. **1** exemplarily illustrates that the encapsulation layer **30** includes three organic layers **31** and three inorganic layers **32**, and the protrusion and depression structure **33** having the surface roughness included in the above-stated range is formed at each interface between the organic layer **31** and the inorganic layer **32**. However, the number of the protrusion and depression structures **33** and the locations of the organic layers **31** and the inorganic layers **32** may be variously and suitably changed.

A manufacturing method of an OLED display according to the present exemplary embodiment will now be described.

A manufacturing method of the OLED display **100**, according to the present exemplary embodiment, includes forming the organic light emitting element **20** including the first electrode **21**, the emission layer **22**, and the second electrode **23** on the substrate **10** and forming the encapsulation layer **30** on the organic light emitting element **20**. The forming of the encapsulation layer **30** includes a first step for forming the organic layer **31**, a second step for forming the protrusion and depression structure **33** in the surface of the organic layer **31** by dry-etching the surface of the organic layer **31**, and a third step for forming the inorganic layer **32** on the organic layer **31** where the protrusion and depression structure **33** is formed.

FIG. 3A to FIG. **3**C are schematically cross-sectional views for describing a manufacturing method of an OLED display according to an exemplary embodiment.

Referring to FIG. 3A, an organic light emitting element **20** is formed on a substrate **10**. The organic light emitting element **20** includes a first electrode **21**, an emission layer **22**, and a second electrode **23**. The first electrode **21**, the emission layer **22**, and the second electrode **23** are formed with materials and methods that are known to the typical OLED display field, and therefore no further description will be provided.

A barrier layer may also be disposed between the substrate **10** and the organic light emitting element **20**, and a driving circuit including a thin film transistor is formed on the substrate **10**. The driving circuit is connected with the organic light emitting element **20** and controls driving of the organic light emitting element **20**.

Subsequently, an organic layer **31** is formed to cover the organic light emitting element **20** (first step). The organic layer **31** may be formed through a heat treatment or deposition method after coating an organic material. The thickness of the organic layer **31** may be 0.01 μm to 5 μm.

Referring to FIG. **3**B, a protrusion and depression structure **33**, having surface roughness of which RMS roughness is in a range between 30 Å to 100 nm and a maximum height (Rmax) is in a range between 50 Å to 200 nm, is formed by dry-etching a surface of the organic layer **31** (second step). The dry-etching may be realized using a plasma enhanced chemical vapor deposition (PECVD) equipment or a plasma etching equipment.

When the organic layer **31** is formed by depositing the organic material in a chamber of the PECVD equipment, the surface of the organic layer **31** can be dry-etched through a continuous process in the same chamber by changing a process condition such as injection gas, pressure, and power. Plasma etching may be realized in another process chamber after forming the organic layer **31**. Ion-beam etching, inductively coupled plasma etching, or reactivity ion etching may be used as the plasma etching.

At least one selected from a group consisting of SiF_4, CF_4, C_3F_8, C_2F_6, CHF_3, $CClF_3$, O_2, NF_3 and SF_6 may be used as the process gas for the dry-etching process. In addition, an inactive gas (i.e., Ar or such as N_2) that does not directly involve etching reaction may be further included to enhance etching reactivity or uniformity of etching.

For the dry-etching performed in the PECVD equipment, the reaction gas may include NF_3. For the ion-beam etching, the process gas may include at least one of C_3F_8, CHF_3, $CClF_3$, and CF_4. For the inductively coupled plasma etching, the process gas may include O_2. For the reactivity ion etching, the process gas may include at least one of SiF_4, CF_4, C_3F_8, C_2F_6, CHF_3, $CClF_3$, O_2, NF_3, and SF_6.

Radio frequency power included in a range between 10 mW to 2,000 W and a process pressure included in a range between 0.1 torr to 10 torr may be applied for the plasma etching. When the above-stated conditions are satisfied, etching uniformity can be acquired and deterioration of a driving characteristic of the organic light emitting element can be suppressed.

A protrusion and depression structure **33** is formed in the surface of the organic layer **31** through the dry-etching, and the protrusion and depression structure **33** has surface roughness of which a root mean square (RMS) is in a range between 30 Å to 100 nm and a maximum height is in a range between 50 Å to 200 nm.

In the first step, a polypethylemethacrylate resin is included as an organic material and the organic layer is dry-etched in the second step. FIG. **4** is an SEM photo of such an organic layer. FIG. **5** is an SEM photo of an organic layer according to a comparative example. The organic layer of the comparative example is formed in the same condition of the exemplary embodiment, except that dry-etching is not performed.

The organic layer according to the comparative example shown in FIG. **5** has a smooth surface of which an RMS roughness and a surface roughness maximum height (Rmax) are about several Å, and the organic layer according to the exemplary embodiment shown in FIG. **4** has a rough surface, that is, a protrusion and depression structure **133**.

Referring to FIG. **3**C, the inorganic layer **32** is formed on the organic layer **31** such that gaps between hollows in the surface of the organic layer **31** are filled with an inorganic material (third step). The inorganic layer **32** may be formed using a deposition or sputtering method. Accordingly, the organic layer **31** and the inorganic layer **32** contact each other, interposing a rough interface therebetween, and realize an excellent adherence performance. The formed encapsulation layer **30**, including the plurality of organic layers **31** and the plurality of inorganic layers **32**, is formed by repeating at least once the first to third steps (refer to FIG. **1**).

FIG. **6** is an SEM photo of a cross-section of the encapsulation layer according to a present exemplary embodiment, and FIG. **7** is an SEM photo of an encapsulation layer according to a comparative example. The encapsulation layer of the comparative example is formed in the same condition of the exemplary embodiment, except that plasma-etching is not performed.

In the encapsulation layer of the comparative example of FIG. **7**, an interface between an organic layer and an inorganic layer is definite and a layer falling-off phenomenon is generated and thus the encapsulation layer is partially damaged. On the other hand, the encapsulation layer according to the exemplary embodiment of FIG. **6** does not have a definite interface between the organic layer and the inorganic layer due to roughness of the interface, and the organic layer and the inorganic layer are firmly adhered to each other without having the layer falling-off phenomenon. Two vertical lines shown in FIG. **6** are provided to indicate the entire thickness of the encapsulation.

The OLED display **100**, provided with the above-stated encapsulation layer **30** according to the present exemplary embodiment can suppress the layer falling-off phenomenon of the encapsulation layer **30**, can enhance a sealing function by blocking penetration of moisture and oxygen to the organic light emitting element **20**, and can improve display quality by reducing reflection of internal and external lights.

While this disclosure has been described in connection with what is presently considered to be practical exemplary embodiments, it is to be understood that the invention is not limited to the disclosed embodiments, but, on the contrary, is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims.

<Description of certain symbols>

100: OLED display	10: substrate
20: organic light emitting element	21: first electrode
22: emission layer	23: second electrode
30: encapsulation layer	31: organic layer
32: inorganic layer	33: protrusion and depression structure

What is claimed is:

1. An organic light emitting diode (OLED) display comprising:

a substrate;

an organic light emitting element on the substrate and comprising a first electrode, an emission layer, and a second electrode; and

an encapsulation layer on the substrate while covering the organic light emitting element,

wherein the encapsulation layer comprises alternately stacked organic layers and inorganic layers, wherein a protrusion and depression structure, with an irregular pattern, is formed in interfaces between the organic layers and the inorganic layers,

wherein the protrusion and depression structure has a root mean square (RMS) roughness in a range between 30 Å to 1000 Å,

wherein each of the organic layers has a refractive index between 1.2 and 2.0,

wherein each of the inorganic layers has a refractive index between 1.3 and 2.2,

wherein the protrusion and depression structure is formed in a surface of the organic layer,

wherein the inorganic layer is formed on the organic layer, and

wherein the protrusion and depression structure consists of the same material as the organic layer.

2. The OLED display of claim **1**, wherein a surface roughness of the protrusion and depression structure has a maximum height (Rmax) in a range between 50 Å to 200 nm.

3. The OLED display of claim **1**, wherein a surface roughness of the protrusion and depression structure has a maximum height (Rmax) in a range between 50 Å to 200 nm.

4. The OLED display of claim **1**, wherein the organic layer and the inorganic layer are respectively provided in plural, and the protrusion and depression structure is formed at each interface where the inorganic layer is layered on the organic layer.

5. The OLED display of claim **1**, wherein the organic layer comprises at least one material selected from a group consisting of a carbide-based material, a carbonate-based material, an acryl-based resin, a methacryl-based resin, polyisoprene, a vinyl-based resin, an epoxy-based resin, a urethane-based resin, a cellulous-based resin, and a perylene-based resin.

6. The OLED display of claim **1**, wherein the inorganic layer comprises at least one material selected from a group consisting of silicon nitride, aluminum nitride, zirconium nitride, titanium nitride, hafnium nitride, tantalum nitride, silicon oxide, aluminum oxide, titanium oxide, tin oxide, cerium oxide, and silicon oxynitride.

7. The OLED display of claim **1**, wherein a refractive index difference between the organic layer and the inorganic layer is higher than 0.1.

* * * * *

patsnap

专利名称(译)	有机发光二极管显示器及其制造方法		
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摘要(译)

OLED显示器包括：基板;有机发光元件，形成在基板上，包括第一电极，发光层和第二电极;形成在基板上的封装层同时覆盖有机发光元件。封装层包括有机层和无机层，并且在有机层和无机层之间的界面中形成突起和凹陷结构。