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(54) METHOD AND SYSTEM HAVING AT LEAST ONE THERMAL TRANSFER STATION FOR MAKING OLED DISPLAYS

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(57) ABSTRACT

Making an OLED device, in a controlled environment, includes positioning a substrate having an electrode in a first station and coating one or more first organic layer(s); using a robot to grasp and remove the substrate from the first station and positioning the coated substrate into a second station, with a donor element that includes emissive organic material; applying radiation to selectively transfer organic material from the donor element to the substrate to form an emissive layer; forming a second electrode in a third station; and controlling the atmosphere in the stations so that the water vapor partial pressure is less than 1 torr but greater than 0 torr, or the oxygen partial pressure is less than 1 torr but greater than 0 torr, or both the water vapor partial pressure and the oxygen partial pressure are respectively less than 1 torr but greater than 0 torr.

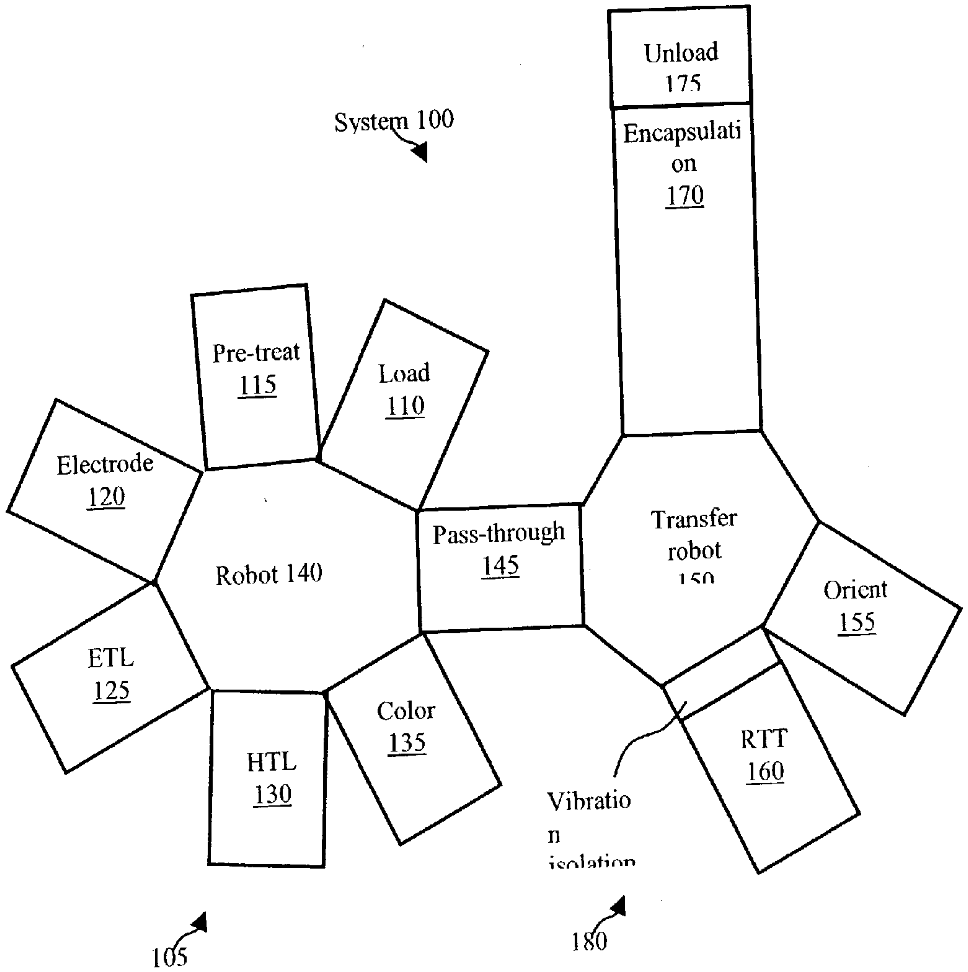


FIG. 1:

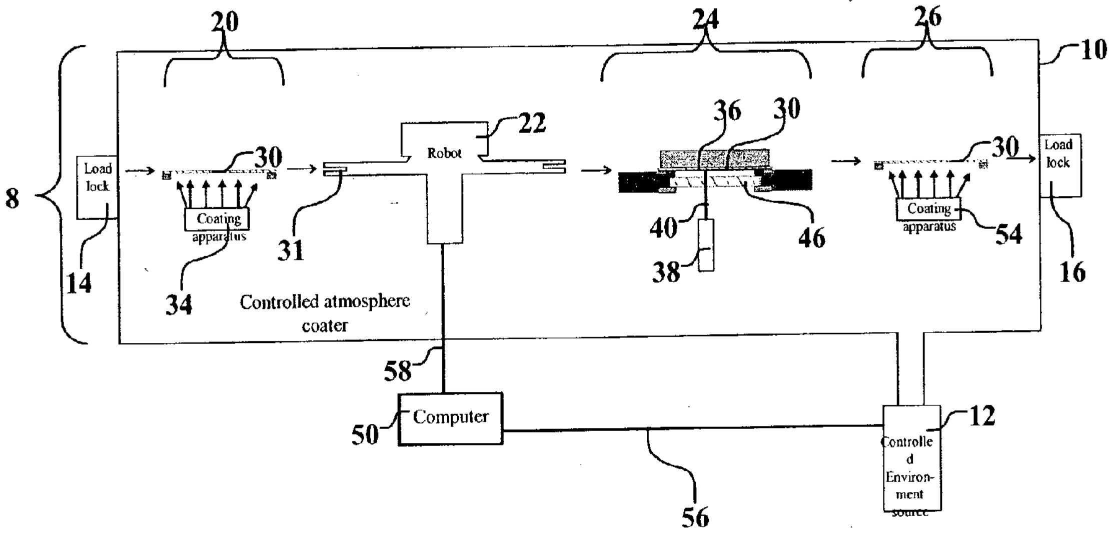

20
24
26
10
8
Load lock
30
22
Robot
36
30
30
Load lock
Coating apparatus
31
40
46
Coating apparatus
54
14
34
38
16
Controlled atmosphere coater
58
Computer
50
12
Controlled Environment source
56

FIG. 2:

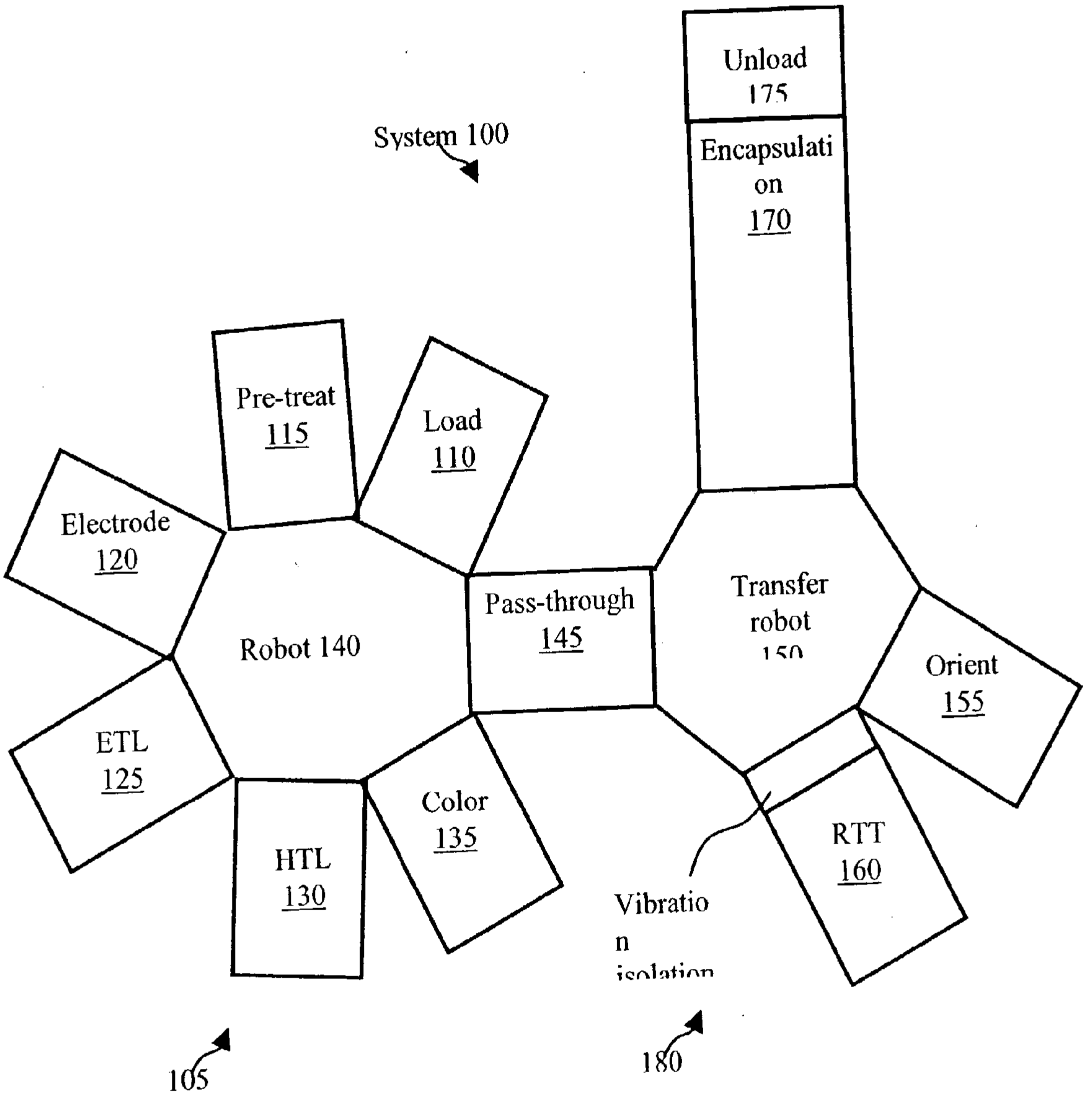

System 100
Unload
175
Encapsulation
170
Pre-treat
115
Load
110
Electrode
120
Robot 140
Pass-through
145
Transfer
robot
150
Orient
155
ETL
125
HTL
130
Color
135
RTT
160
Vibration
isolation
105
180

FIG. 3:

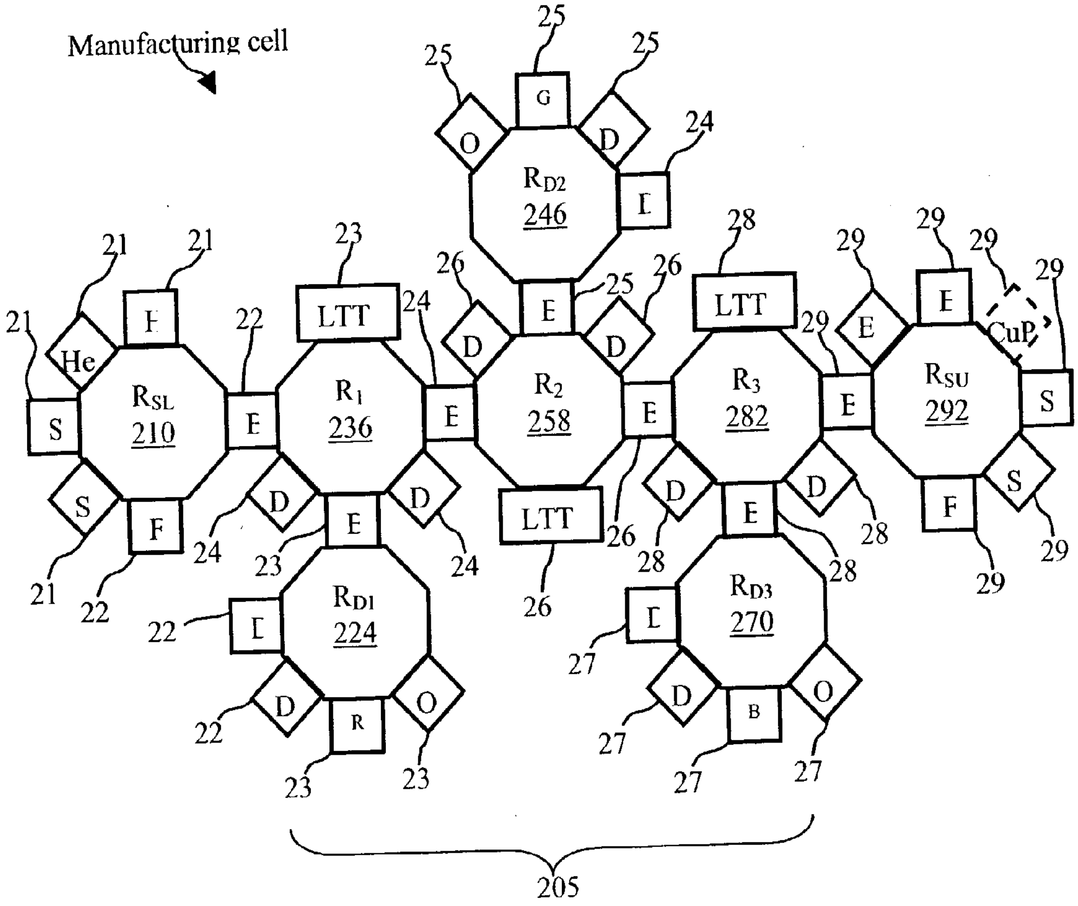

Manufacturing cell
25
25
25
O
G
D
24
R_{D2}
246
E
23
LTT
24
26
D
E
25
26
D
28
LTT
29
29
29
29
E
E
CuP
29
21
21
21
He
F
22
S
R_{SL}
210
E
R_1
236
E
R_2
258
E
R_3
282
E
R_{SU}
292
S
S
D
F
D
E
D
LTT
D
E
D
F
S
21
22
24
23
24
26
26
28
28
28
29
29
22
E
R_{D1}
224
E
R_{D3}
270
27
D
R
O
D
B
O
22
23
23
27
27
27
205

FIG. 4:

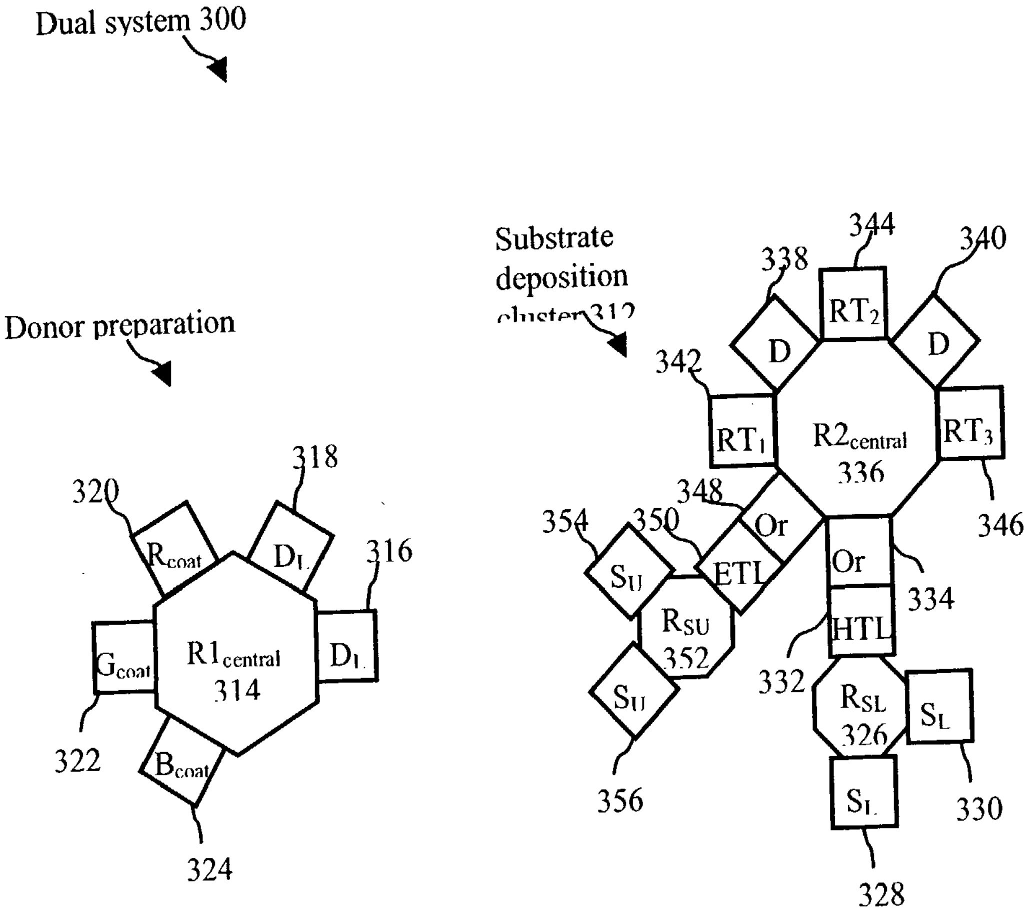

Dual system 300
Donor preparation
Substrate deposition cluster 312
R1central 314
Rcoat
DL
DL
Gcoat
Bcoat
320
318
316
322
324
R2central 336
RT2
D
D
RT1
RT3
Or
Or
ETL
HTL
RSU 352
SU
SU
RSL 326
SL
SL
344
338
340
342
346
348
350
354
334
332
356
330
328

FIG. 5:

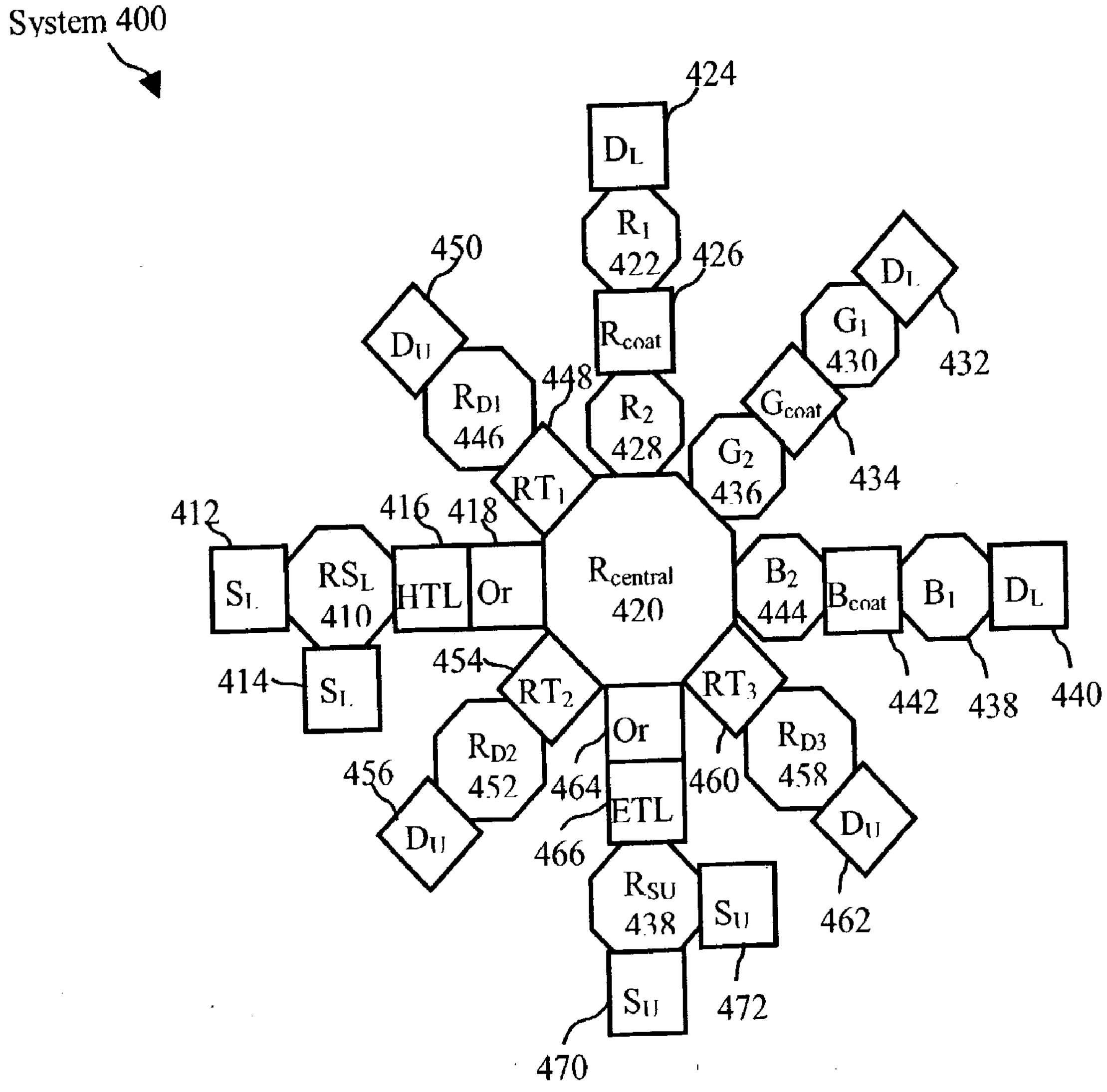

System 400
424
D_L
R_1 422
426
R_{coat}
450
D_U
R_{D1} 446
448
R_2 428
D_L
432
G_1 430
G_{coat}
434
G_2 436
RT_1
412
416
418
S_L
RS_L 410
HTL
Or
$R_{central}$ 420
B_2 444
B_{coat}
B_1
D_L
414
S_L
454
RT_2
RT_3
442
438
440
Or
R_{D2} 452
R_{D3} 458
456
464
460
D_U
ETL
D_U
466
462
R_{SU} 438
S_U
472
S_U
470

FIG. 6:

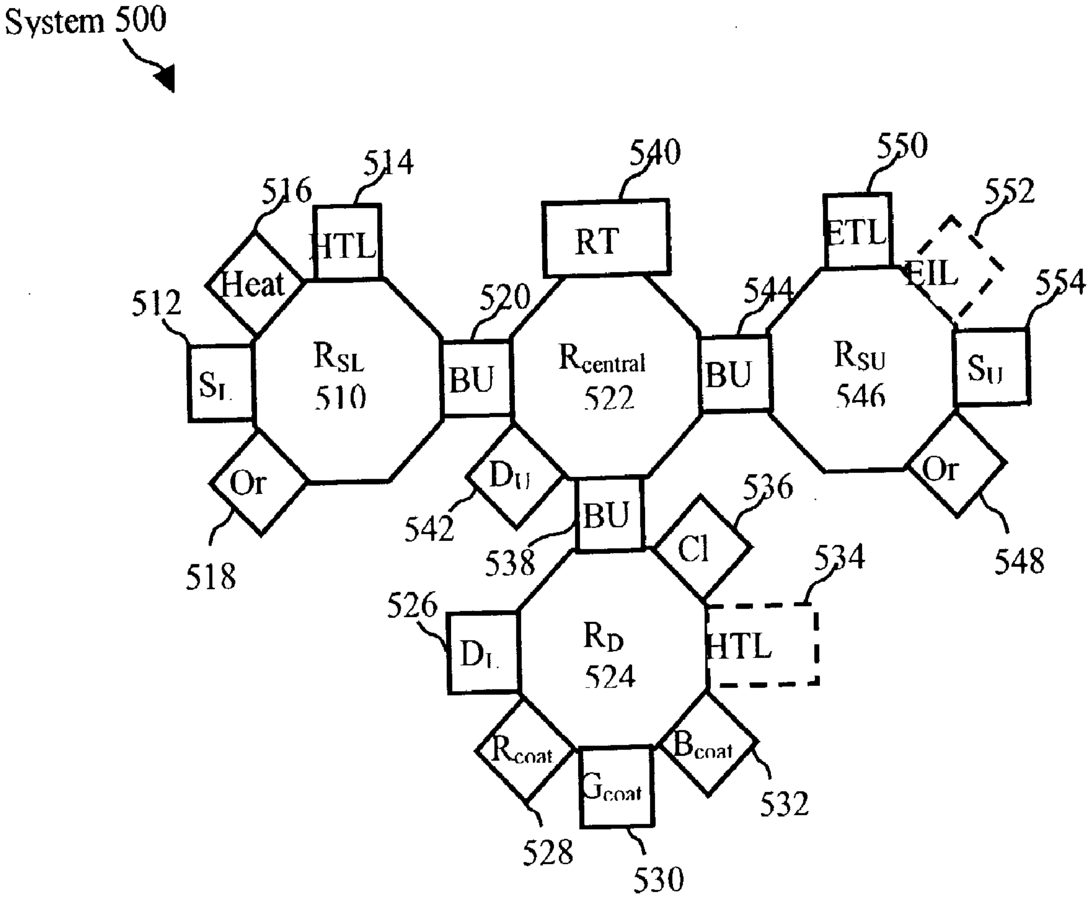

System 500
514
516
HTL
Heat
512
S_L
R_{SL} 510
Or
518
540
RT
520
BU
$R_{central}$ 522
D_U
542
BU
538
550
ETL
552
EIL
544
BU
R_{SU} 546
554
S_U
Or
548
536
Cl
534
HTL
526
D_L
R_D 524
R_{coat}
528
G_{coat}
530
B_{coat}
532

FIG. 7:

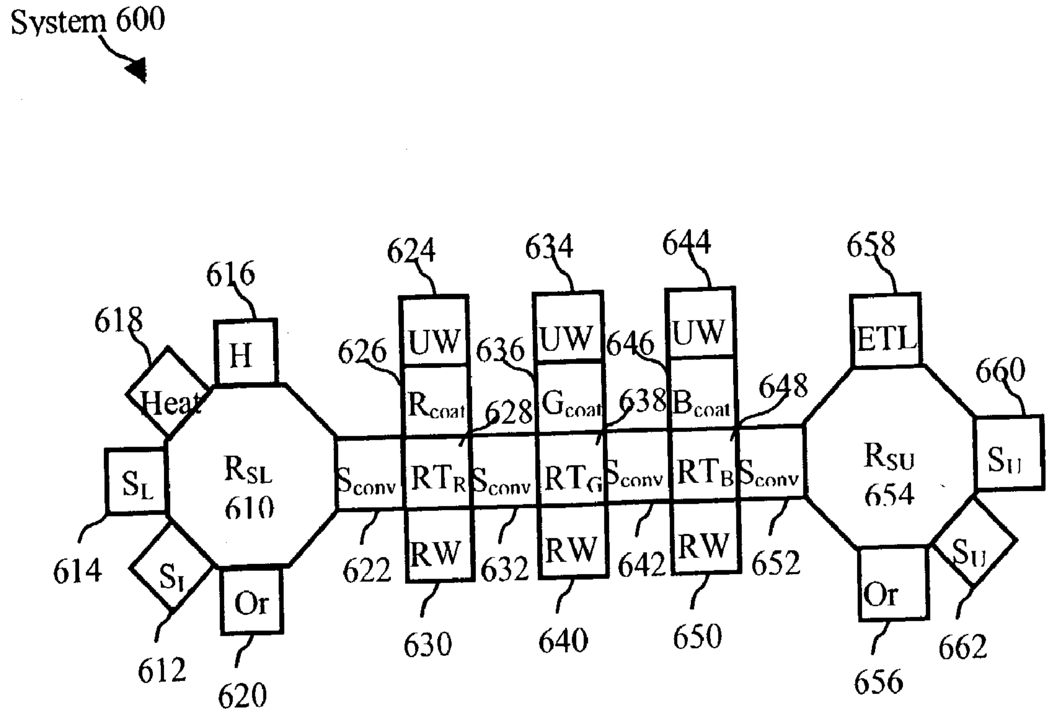

System 600
618
616
624
634
644
658
626
636
646
660
648
628
638
Heat
H
UW
UW
UW
ETL
R_{coat}
G_{coat}
B_{coat}
S_L
R_{SL}
610
S_{conv}
RT_R
S_{conv}
RT_G
S_{conv}
RT_B
S_{conv}
R_{SU}
654
S_U
S_I
Or
RW
RW
RW
Or
S_U
614
622
632
642
652
612
620
630
640
650
656
662

FIG. 8:

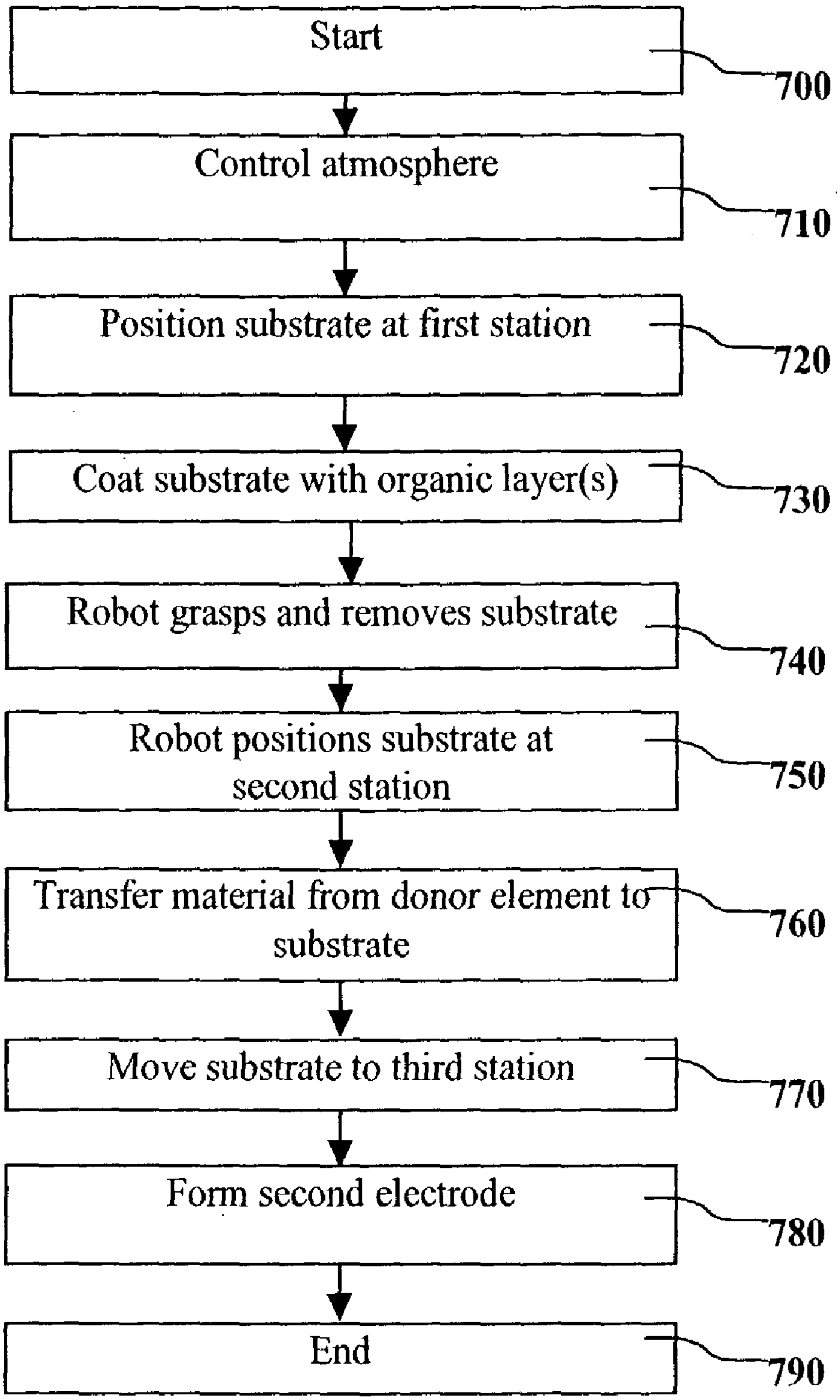
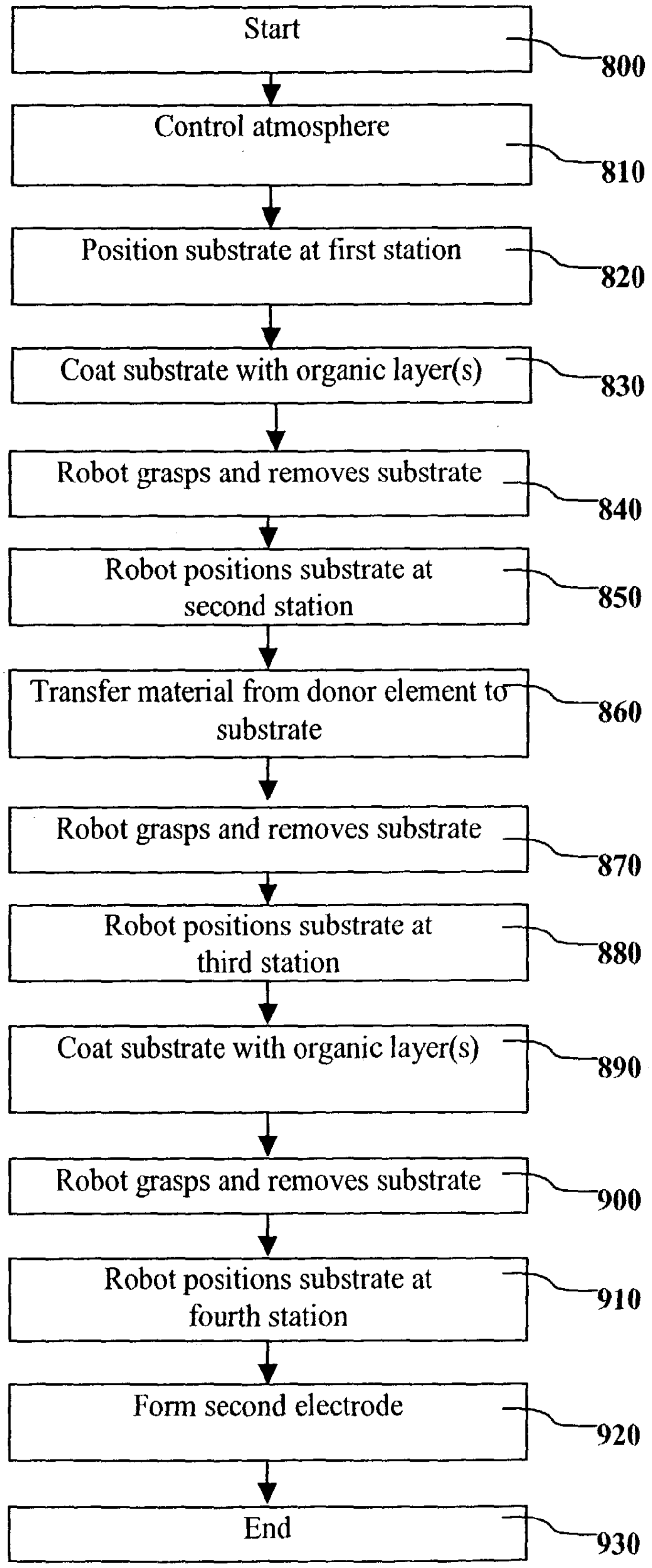

Start
700
Control atmosphere
710
Position substrate at first station
720
Coat substrate with organic layer(s)
730
Robot grasps and removes substrate
740
Robot positions substrate at second station
750
Transfer material from donor element to substrate
760
Move substrate to third station
770
Form second electrode
780
End
790

FIG. 9:


Start
800
Control atmosphere
810
Position substrate at first station
820
Coat substrate with organic layer(s)
830
Robot grasps and removes substrate
840
Robot positions substrate at second station
850
Transfer material from donor element to substrate
860
Robot grasps and removes substrate
870
Robot positions substrate at third station
880
Coat substrate with organic layer(s)
890
Robot grasps and removes substrate
900
Robot positions substrate at fourth station
910
Form second electrode
920
End
930

METHOD AND SYSTEM HAVING AT LEAST ONE THERMAL TRANSFER STATION FOR MAKING OLED DISPLAYS

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] Reference is made to commonly assigned U.S. patent application Ser. No. 10/021,410, filed Dec. 12, 2001, entitled "Apparatus for Permitting Transfer of Organic Material From a Donor to Form a Layer in an OLED Device" by Bradley A. Phillips et al, U.S. patent application Ser. No. 10/141,587, filed May 8, 2002, entitled "In-Situ Method for Making OLED Devices That are Moisture or Oxygen-Sensitive" by Michael L. Boroson et al, U.S. patent application Ser. No. 10/211,213, filed Aug. 2, 2002, entitled "Laser Thermal Transfer From a Donor Element Containing a Hole-Transporting Layer" by Myron W. Culver et al, U.S. patent application Ser. No. 10/224,182 filed Aug. 20, 2002, entitled "Apparatus for Permitting Transfer of Organic Material From a Donor Web to Form a Layer in an OLED Device" by Bradley A. Phillips et al; the disclosures of which are incorporated herein by reference.

FIELD OF THE INVENTION

[0002] The present invention relates to making organic light-emitting diode (OLED) displays having at least one station that uses thermal transfer.

BACKGROUND OF THE INVENTION

[0003] OLED displays are one of the most recent flat panel display technologies and are predicted to overtake LCD display technology within the next decade. OLED displays offer brighter displays, significantly wider viewing angles, lower power requirements, and longer lifetimes than their LCD counterparts. OLED technology offers more display flexibility and alternatives to backlit LCD displays. For example, OLED displays may be made of thin, flexible materials that conform to any desired shape for specific applications. However, OLED displays and their components known as OLED structures, which constitute subpixels of the display, are more difficult and costly to manufacture than LCD displays. It is a continuing focus of the industry to increase throughput in an effort to lower the cost of OLED manufacturing.

[0004] Conventional OLED display devices are built on glass substrates in a manner such that a two-dimensional OLED array for image manifestation is formed. The basic OLED cell structure consists of a stack of thin organic layers sandwiched between one or more anode(s) and one or more metallic cathode(s). The organic layers typically comprise a hole transport layer (HTL), an emissive layer (EL), and an electron transport layer (ETL). When an appropriate voltage is applied to the cell, the injected holes and electrons recombine in the emissive layer near the EL-HTL interface to produce light (electroluminescence). In conventional OLED manufacturing, linear or point source vacuum deposition processes are used to deposit the organic materials on to the substrate.

[0005] The emissive layer within a color OLED display device most commonly includes three different types of fluorescent materials that are repeated through the emissive layer. Red, green, and blue regions, or subpixels, are formed throughout the emissive layer during the manufacturing process to provide a two-dimensional array of pixels. Each of the red, green, and blue subpixel sets undergoes a separate patterned deposition, for example, by evaporating a linear source through a shadow mask. Linear source vacuum deposition with shadow masking is a well-known technology, yet it is limited in the precision of its deposition pattern and in the pattern's fill factor or aperture ratio; thus, incorporating shadow masking into a manufacturing scheme limits the achievable sharpness and resolution of the resultant display. Radiation thermal transfer promises a more precise deposition pattern and higher aperture ratio; however, it has proved challenging to adapt radiation thermal transfer to a high throughput manufacturing line, which is necessary to warrant its use in the manufacture of cost-effective OLED display devices.

[0006] During radiation thermal transfer, a donor sheet having the desired organic material is typically placed into close proximity to the OLED substrate within a vacuum chamber. A radiation source impinges through a support that provides physical integrity to the donor sheet and is absorbed within a radiation-absorbing layer contained atop the support. The conversion of the radiation source's energy to heat transfers the organic material that forms the top layer of the donor sheet and thereby transfers the organic material in a desired subpixel pattern to the OLED substrate.

[0007] The combination of traditional linear source based deposition processes with radiation thermal transfer processes would allow the advantages of both processes to be applied to OLED manufacturing. However, OLED organics are particularly susceptible to damage from environmental exposure, especially to moisture, oxygen, and ultraviolet light. The challenge is to integrate the various processes in a way that is both cost effective and fully controls the environment of the OLED.

[0008] U.S. Pat. No. 6,485,884, entitled, "Method for patterning oriented materials for organic electronic displays and devices," provides a method for patterning oriented materials to make OLED display devices, and also provides donor sheets for use with the method, as well as methods for making the donor sheets. However, the '884 patent fails to provide a system that enables radiation thermal transfer to be combined with more conventional deposition techniques, such as linear evaporation through a shadow mask, to form a manufacturing system that is scalable and capable of the throughput necessary to enable the cost-effective manufacture of OLED display devices.

SUMMARY OF THE INVENTION

[0009] It is therefore an object of the present invention to provide a more effective way of making OLED displays.

[0010] This object is achieved in a method of making an OLED device comprising, in a controlled environment, the steps of:

> **[0011]** a) positioning a substrate having an electrode in a first station and coating one or more first organic layer(s) over the substrate;
>
> **[0012]** b) using a robot to grasp and remove the substrate from the first station and positioning the coated substrate into a second station, in material

transferring relationship with a donor element that includes emissive organic material;

[0013] c) applying radiation to the donor element to selectively transfer organic material from the donor element to the substrate to form an emissive layer on the coated substrate;

[0014] d) forming a second electrode in a third station over the one or more second organic layers of the emissive coated substrate; and

[0015] e) controlling the atmosphere in the first, second, and third stations and in which the robot operates so that the water vapor partial pressure is less than 1 torr but greater than 0 torr, or the oxygen partial pressure is less than 1 torr but greater than 0 torr, or both the water vapor partial pressure and the oxygen partial pressure are respectively less than 1 torr but greater than 0 torr.

[0016] The present invention makes use of at least one robot to provide a more effective way of making OLED displays. An advantage of the method described in this invention is that it is useful in producing OLED devices without introducing moisture, oxygen, or other atmospheric components.

[0017] A further advantage is that this method can be fully automated including donor and substrate media handling. The present invention is particularly suitable for forming organic layers over a large area having a number of OLED display devices, which are in the process of being formed, thereby increasing throughput.

[0018] A further advantage is that added techniques can be used for coating, including solvent-based coating such as spin coating, curtain coating, spray coating, Gravure-wheel coating, and others.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] **FIG. 1** is a cross-sectional representation of a first embodiment of an apparatus including a first, second, and third stations to effect this invention;

[0020] **FIG. 2** illustrates a manufacturing system including a series of stations in accordance with the present invention;

[0021] **FIG. 3** illustrates an alternate embodiment of a manufacturing system including a series of stations in accordance with the present invention;

[0022] **FIG. 4** illustrates an alternate embodiment of a manufacturing system including a series of stations in accordance with the present invention;

[0023] **FIG. 5** illustrates an alternate embodiment of a manufacturing system including a series of stations in accordance with the present invention;

[0024] **FIG. 6** illustrates an alternate embodiment of a manufacturing system including a series of stations in accordance with the present invention;

[0025] **FIG. 7** an alternate embodiment of a manufacturing system including a series of stations in accordance with the present invention;

[0026] **FIG. 8** is a block diagram showing the steps in one embodiment of the present invention;

[0027] **FIG. 9** is a block diagram showing the steps in another embodiment of the present invention.

[0028] Since device feature dimensions such as layer thicknesses are frequently in sub-micrometer ranges, the drawings are scaled for ease of visualization rather than dimensional accuracy.

DETAILED DESCRIPTION OF THE INVENTION

[0029] The term "OLED device" refers to a device including organic light-emitting diodes, sometimes called an electroluminescent device, and an EL device, as described by e.g. Tang in commonly assigned U.S. Pat. No. 5,937,272 and by Littman and Tang in commonly assigned U.S. Pat. No. 5,688,551. The term "display" or "display panel" is employed to designate a screen capable of electronically displaying video images or text. The term "pixel" is employed in its art-recognized usage to designate an area of a display panel that can be stimulated to emit light independently of other areas. The term "multicolor" is employed to describe a display panel that is capable of emitting light of a different hue in different areas. In particular, it is employed to describe a display panel that is capable of displaying images of different colors. These areas are not necessarily contiguous. The term "full color" is employed to describe multicolor display panels that are capable of emitting in the red, green, and blue regions of the visible spectrum and displaying images in any combination of hues. The red, green, and blue colors constitute the three primary color from which all other colors can be generated by appropriately mixing these three primaries. The term "hue" refers to the intensity profile of light emission within the visible spectrum, with different hues exhibiting visually discernible differences in color. The pixel or subpixel is generally used to designate the smallest addressable unit in a display panel. For a monochrome display, there is no distinction between pixel or subpixel. The term "subpixel" is used in multicolor display panels and is employed to designate any portion of a pixel which can be independently addressable to emit a specific color. For example, a blue subpixel is that portion of a pixel which can be addressed to emit blue light. In a full-color display, a pixel generally includes three primary-color subpixels, namely blue, green, and red. The term "pitch" is used to designate the distance separating two pixels or subpixels in a display panel. Thus, a subpixel pitch means the separation between two subpixels. The term "vacuum" is used herein to designate a pressure of 1 torr or less.

[0030] The present invention combines a radiation thermal transfer deposition subsystem(s) with conventional deposition subsystems to form an automated and scalable manufacturing system that provides a controlled environment throughout the entire manufacturing process. Such mixed-mode deposition under controlled environment is particularly well suited to the manufacture of OLED display devices.

[0031] Turning now to **FIG. 1**, we see a cross-sectional representation of one embodiment of this invention in which an OLED substrate **30** is coated in three stations in the same controlled atmosphere coater **8**. Controlled atmosphere coater **8** is an enclosed apparatus described herein that permits an in-situ method for fabricating an OLED device under controlled-environment conditions and includes unitary housing **10** which encompasses a first, second, and third stations and a robot. By controlled environment, we mean that the water vapor partial pressure is preferably 1 torr or less, or the oxygen partial pressure is preferably 1 torr or less, or both. This can be accomplished by maintaining a vacuum inside the controlled atmosphere coater **8**. This can also be accomplished by maintaining a water vapor level of preferably 1000 ppm or less, or an oxygen level of preferably 1000 ppm or less, or both, at a total pressure greater than 1 torr inside controlled atmosphere coater **8**. While controlled atmosphere coater **8** is shown as a single chamber, it can also include two or more chambers in which at least one chamber is maintained under a vacuum, and at least one chamber is maintained under a higher-pressure controlled environment as described above. Such an apparatus has been described previously by Boroson et al in above-cited commonly-assigned U.S. patent application Ser. No. 10/141,587. While it is impossible to reduce the quantities of water vapor and/or oxygen completely to zero, controlled environment conditions can reduce the quantities of these components to very low or imperceptible levels, such as 0.001 ppm. Controlling the environment can be achieved by various well-known methods, e.g. oxygen or water-vapor scrubbers, or the use of purified gasses. Controlled atmosphere coater **8** can include one chamber, or any number of chambers that can be connected by load locks or similarly-acting apparatus such as tunnels or buffer chambers, whereby donor elements and receiver elements can be transported without exposure to moisture and/or oxygen. The conditions are maintained in controlled atmosphere coater **8** by a means for controlling the atmosphere, e.g. controlled-environment source **12**. Controlled atmosphere coater **8** can include load lock **14**, which is used to load substrates **30**, and load lock **16**, which is used to unload completed OLED devices. Several embodiments of controlled atmosphere coater **8** have been more fully described by Boroson et al in above-cited commonly-assigned U.S. patent application Ser. No. 10/141,587.

[0032] The interior of this embodiment of controlled atmosphere coater **8** can include first station **20**, robot **22**, second station **24**, and third station **26**. It will be understood in this and subsequent systems that "first station", "second station", etc. are terms of convenience and do not necessarily imply a specific order of operation. In this embodiment, first, second, and third stations **20**, **24**, and **26** are sequentially positioned in line, so that the substrate **30** can be sequentially moved in line through the different stations. First station **20** is a means for coating one or more organic layers over the substrate **30** e.g. a structure for applying a hole-transporting material over the substrate **30** by e.g. vapor deposition or other substantially uniform means. Substrate **30** can be an organic solid, an inorganic solid, or a combination of organic and inorganic solids that provides a surface for receiving the emissive organic material from a donor. Substrate **30** can be rigid or flexible and can be processed as separate individual pieces, such as sheets or wafers, or as a continuous roll. Typical substrate element materials include glass, plastic, metal, ceramic, semiconductor, metal oxide, semiconductor oxide, semiconductor nitride, or combinations thereof. Substrate **30** can be a homogeneous mixture of materials, a composite of materials, or multiple layers of materials. Substrate **30** can be an OLED substrate, that is a substrate commonly used for preparing OLED devices, e.g. active-matrix low-temperature polysilicon TFT substrate. The substrate **30** can either be light transmissive or opaque, depending on the intended direction of light emission. The light transmissive property is desirable for viewing the EL emission through substrate **30**. Transparent glass or plastic are commonly employed in such cases. For applications where the EL emission is viewed through the top electrode, the transmissive characteristic of substrate **30** is immaterial, and therefore can be light transmissive, light absorbing or light reflective. Substrate elements for use in this case include, but are not limited to, glass, plastic, semiconductor materials, ceramics, and circuit board materials.

[0033] Substrate **30** commonly includes a first electrode. The first electrode is most commonly an anode, although examples of cathodes on an OLED substrate are known in the art. The conductive anode layer is formed over the substrate and, when EL emission is viewed through the anode, should be transparent or substantially transparent to the emission of interest. Common transparent anode materials used in this invention are indium-tin oxide and tin oxide, but other metal oxides can work including, but not limited to, aluminum- or indium-doped zinc oxide, magnesium-indium oxide, and nickel-tungsten oxide. In addition to these oxides, metal nitrides, such as gallium nitride, and metal selenides, such as zinc selenide, and metal sulfides, such as zinc sulfide, can be used as an anode material. For applications where EL emission is viewed through the top electrode, the transmissive characteristics of the anode material are immaterial and any conductive material can be used, transparent, opaque or reflective. Examples of conductors for this application include, but are not limited to, gold, iridium, molybdenum, palladium, and platinum. Typical anode materials, transmissive or otherwise, have a work function of 4.1 eV or greater. Desired anode materials can be deposited by any suitable means such as evaporation, sputtering, chemical vapor deposition, or electrochemical means. Anode materials can be patterned using well-known photolithographic processes.

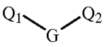
[0034] Coating means or coating apparatus **34** can represent e.g. a heated boat, a point vapor source, etc. It will be understood that other coating methods are possible, e.g. solvent coating, and that the relative positions of substrate **30** above or below coating apparatus **34** will depend on the type of coating. First station **20** can coat one or more organic layers on substrate **30**. For example, the use of two or more coating apparatus **34**, movable in relation to substrate **30**, will allow multiple organic layers to be coated.

[0035] First station **20** can coat one or more organic layer(s), e.g. a hole-injecting layer or a hole-transporting layer. While not always necessary, it is often useful that a hole-injecting layer be provided in an organic light-emitting display. The hole-injecting material can serve to improve the film formation property of subsequent organic layers and to facilitate injection of holes into the hole-transporting layer. Suitable materials for use in the hole-injecting layer include, but are not limited to, porphyrinic compounds as described in commonly-assigned U.S. Pat. No. 4,720,432, and plasma-deposited fluorocarbon polymers as described in commonly-assigned U.S. Pat. No. 6,208,075. Alternative hole-injecting materials reportedly useful in organic EL devices are described in EP 0 891 121 A1 and EP 1,029,909 A1.

[0036] Hole-transporting materials useful as coated material are well known to include compounds such as an aromatic tertiary amine, where the latter is understood to be a compound containing at least one trivalent nitrogen atom that is bonded only to carbon atoms, at least one of which is a member of an aromatic ring. In one form the aromatic tertiary amine can be an arylamine, such as a monoarylamine, diarylamine, triarylamine, or a polymeric arylamine. Exemplary monomeric triarylamines are illustrated by Klupfel et al. U.S. Pat. No. 3,180,730. Other suitable triarylamines substituted with one or more vinyl radicals and/or comprising at least one active hydrogen containing group are disclosed by Brantley et al commonly-assigned U.S. Pat. Nos. 3,567,450 and 3,658,520.

[0037] A more preferred class of aromatic tertiary amines are those which include at least two aromatic tertiary amine moieties as described in commonly-assigned U.S. Pat. Nos. 4,720,432 and 5,061,569. Such compounds include those represented by structural formula (A).

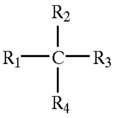
A



[0038] wherein Q_1 and Q_2 are independently selected aromatic tertiary amine moieties and G is a linking group such as an arylene, cycloalkylene, or alkylene group of a carbon to carbon bond. In one embodiment, at least one of Q_1, or Q_2 contains a polycyclic fused ring structure, e.g., a naphthalene. When G is an aryl group, it is conveniently a phenylene, biphenylene, or naphthalene moiety.

[0039] A useful class of triarylamines satisfying structural formula (A) and containing two triarylamine moieties is represented by structural formula (B):

B

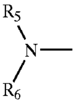


$$R_1—\overset{\displaystyle R_2}{\underset{\displaystyle R_4}{\overset{|}{\underset{|}{C}}}}—R_3$$

[0040] where R_1 and R_2 each independently represents a hydrogen atom, an aryl group, or an alkyl group or R_1 and R_2 together represent the atoms completing a cycloalkyl group; and

[0041] R_3 and R_4 each independently represents an aryl group, which is in turn substituted with a diaryl substituted amino group, as indicated by structural formula (C):

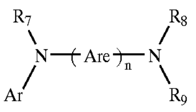
C



[0042] wherein R_5 and R_6 are independently selected aryl groups. In one embodiment, at least one of R_5 or R_6 contains a polycyclic fused ring structure, e.g., a naphthalene.

[0043] Another class of aromatic tertiary amines are the tetraaryldiamines. Desirable tetraaryldiamines include two diarylamino groups, such as indicated by formula (C), linked through an arylene group. Useful tetraaryldiamines include those represented by formula (D).

D



[0044] wherein each Are is an independently selected arylene group, such as a phenylene or anthracene moiety,

[0045] n is an integer of from 1 to 4, and

[0046] Ar, R_7, R_8, and R_9 are independently selected aryl groups.

[0047] In a typical embodiment, at least one of Ar, R_7, R_8, and R_9 is a polycyclic fused ring structure, e.g., a naphthalene.

[0048] The various alkyl, alkylene, aryl, and arylene moieties of the foregoing structural formulae (A), (B), (C), (D), can each in turn be substituted. Typical substituents include alkyl groups, alkoxy groups, aryl groups, aryloxy groups, and halogen such as fluoride, chloride, and bromide. The various alkyl and alkylene moieties typically contain from about 1 to 6 carbon atoms. The cycloalkyl moieties can contain from 3 to about 10 carbon atoms, but typically contain five, six, or seven ring carbon atoms—e.g., cyclopentyl, cyclohexyl, and cycloheptyl ring structures. The aryl and arylene moieties are usually phenyl and phenylene moieties.

[0049] The hole-transporting layer can be formed of a single or a mixture of aromatic tertiary amine compounds. Specifically, one can employ a triarylamine, such as a triarylamine satisfying the formula (B), in combination with a tetraaryldiamine, such as indicated by formula (D). When a triarylamine is employed in combination with a tetraaryldiamine, the latter is positioned as a layer interposed between the triarylamine and the electron injecting and transporting layer. Illustrative of useful aromatic tertiary amines are the following:

[0050] 1, 1-Bis(4-di-p-tolylaminophenyl)cyclohexane

[0051] 1, 1-Bis(4-di-p-tolylaminophenyl)-4-phenylcyclohexane

[0052] 4,4'-Bis(diphenylamino)quadriphenyl

[0053] Bis(4-dimethylamino-2-methylphenyl)-phenylmethane

[0054] N,N,N-Tri(p-tolyl)amine

[0055] 4-(di-p-tolylamino)-4'-[4(di-p-tolylamino)-styryl]stilbene

[0056] N,N,N',N'-Tetra-p-tolyl-4-4'-diaminobiphenyl

[0057] N,N,N',N'-Tetraphenyl-4,4'-diaminobiphenyl

[0058] N-Phenylcarbazole

[0059] Poly(N-vinylcarbazole), and

[0060] N,N'-di-1-naphthalenyl-N,N'-diphenyl-4,4'-diaminobiphenyl.

[0061] 4,4'-Bis[N-(1-naphthyl)-N-phenylamino]biphenyl

[0062] 4,4"-Bis[N-(1-naphthyl)-N-phenylamino]p-terphenyl

[0063] 4,4'-Bis[N-(2-naphthyl)-N-phenylamino]biphenyl

[0064] 4,4'-Bis[N-(3-acenaphthenyl)-N-phenylamino]biphenyl

[0065] 1,5-Bis[N-(1-naphthyl)-N-phenylamino]naphthalene

[0066] 4,4'-Bis[N-(9-anthryl)-N-phenylamino]biphenyl

[0067] 4,4"-Bis[N-(1-anthryl)-N-phenylamino]-p-terphenyl

[0068] 4,4'-Bis[N-(2-phenanthryl)-N-phenylamino]biphenyl

[0069] 4,4'-Bis[N-(8-fluoranthenyl)-N-phenylamino]biphenyl

[0070] 4,4'-Bis[N-(2-pyrenyl)-N-phenylamino]biphenyl

[0071] 4,4'-Bis[N-(2-naphthacenyl)-N-phenylamino]biphenyl

[0072] 4,4'-Bis[N-(2-perylenyl)-N-phenylamino]biphenyl

[0073] 4,4'-Bis[N-(1-coronenyl)-N-phenylamino]biphenyl

[0074] 2,6-Bis(di-p-tolylamino)naphthalene

[0075] 2,6-Bis[di-(1-naphthyl)amino]naphthalene

[0076] 2,6-Bis[N-(1-naphthyl)-N-(2-naphthyl)amino]naphthalene

[0077] N,N,N',N'-Tetra(2-naphthyl)-4,4"-diamino-p-terphenyl

[0078] 4,4'-Bis {N-phenyl-N-[4-(1-naphthyl)-phenyl]amino}biphenyl

[0079] 4,4'-Bis[N-phenyl-N-(2-pyrenyl)amino]biphenyl

[0080] 2,6-Bis[N,N-di(2-naphthyl)amine]fluorene

[0081] 1,5-Bis[N-(1-naphthyl)-N-phenylamino]naphthalene

[0082] Another class of useful hole-transport materials includes polycyclic aromatic compounds as described in EP 1 009 041. In addition, polymeric hole-transporting materials can be used such as poly(N-vinylcarbazole) (PVK), polythiophenes, polypyrrole, polyaniline, and copolymers such as poly(3,4-ethylenedioxythiophene)/poly(4-styrenesulfonate) also called PEDOT/PSS.

[0083] Controlled atmosphere coater **8** also includes the robot **22**. Robot **22** is an actuable robot control means for grasping and removing substrate **30** from first station **20** after substrate **30** has been coated, and positioning coated substrate **30** into second station **24** so that it is in a material transferring relationship with donor element **36**. For the purposes of this discussion, a robot shall include the apparatus necessary to move a web in the case where substrate **30** is in the form of a continuous web or roll. Robot **22** can include a grasping means **31** by which it can grasp and remove substrate **30** from first station **20** and position the coated substrate **30** in second station **24**.

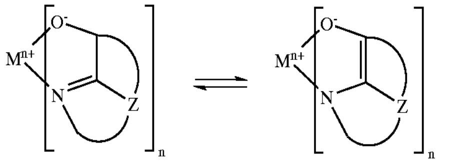
[0084] Second station **24** is a station that can hold substrate **30** in a material transferring relationship with donor element **36**, which includes emissive organic material. Second station **24** can be e.g. an apparatus such as that described by Phillips et al in above cited commonly-assigned U.S. patent application Ser. No. 10/021,410. Second station **24** is shown for convenience in the closed configuration, but it also has an open configuration in which the donor element and substrate loading and unloading occurs. By material transferring relationship we mean the coated side of donor element **36** is positioned in close contact with the receiving surface of substrate **30** and held in place by a means such as fluid pressure in a pressure chamber, as described by Phillips, et al. Second station **24** is constructed so as to facilitate forming an emissive layer on substrate **30** through the selective transfer of organic material from donor element **36** to substrate **30** by applying radiation from an actuable radiation means, e.g. a laser beam **40** from a laser **38**, through transparent portion **46**. Radiation transfer is herein defined as any mechanism such as sublimation, ablation, vaporization or other process whereby material can be transferred upon initiation by radiation. The irradiation of donor element **36** in a predetermined pattern selectively transfers one or more layers of coated material from donor element **36** to substrate **30** so that material will coat selected portions of substrate **30**, as described by Phillips et al.

[0085] The emissive layer includes one or more emissive organic materials. Emissive organic materials useful as coated material are well known. As more fully described in commonly-assigned U.S. Pat. Nos. 4,769,292 and 5,935,721, the emissive layer (LEL) of the organic EL element include a luminescent or fluorescent material where electroluminescence is produced as a result of electron-hole pair recombination in this region. The emissive layer can be comprised of a single material, but more commonly consists of a host material doped with a guest compound or compounds where light emission comes primarily from the dopant and can be of any color. The host materials in the emissive layer can be an electron-transporting material, as defined below, a hole-transporting material, as defined above, or another material that supports hole-electron recombination. The dopant is usually chosen from highly fluorescent dyes, but phosphorescent compounds, e.g., transition metal complexes as described in WO 98/55561, WO 00/18851, WO 00/57676, and WO 00/70655 are also useful. Dopants are typically coated as 0.01 to 10% by weight into the host material.

[0086] An important relationship for choosing a dye as a dopant is a comparison of the bandgap potential which is defined as the energy difference between the highest occupied molecular orbital and the lowest unoccupied molecular orbital of the molecule. For efficient energy transfer from the host to the dopant molecule, a necessary condition is that the band gap of the dopant is smaller than that of the host material.

[0087] Host and emitting molecules known to be of use include, but are not limited to, those disclosed in U.S. Pat. Nos. 4,768,292; 5,141,671; 5,150,006; 5,151,629; 5,294,870; 5,405,709; 5,484,922; 5,593,788; 5,645,948; 5,683,823; 5,755,999; 5,928,802; 5,935,720; 5,935,721, and 6,020,078.

[0088] Metal complexes of 8-hydroxyquinoline and similar derivatives (Formula E) constitute one class of useful host compounds capable of supporting electroluminescence, and are particularly suitable for light emission of wavelengths longer than 500 nm, e.g., green, yellow, orange, and red.



E

[0089] wherein

[0090] M represents a metal;

[0091] n is an integer of from 1 to 3; and

[0092] Z independently in each occurrence represents the atoms completing a nucleus having at least two fused aromatic rings.

[0093] From the foregoing it is apparent that the metal can be monovalent, divalent, or trivalent metal. The metal can, for example, be an alkali metal, such as lithium, sodium, or potassium; an alkaline earth metal, such as magnesium or calcium; or an earth metal, such as boron or aluminum. Generally any monovalent, divalent, or trivalent metal known to be a useful chelating metal can be employed.

[0094] Z completes a heterocyclic nucleus containing at least two fused aromatic rings, at least one of which is an azole or azine ring. Additional rings, including both aliphatic and aromatic rings, can be fused with the two required rings, if required. To avoid adding molecular bulk without improving on function the number of ring atoms is usually maintained at 18 or less.

[0095] Illustrative of useful chelated oxinoid compounds are the following:

[0096] CO-1: Aluminum trisoxine [alias, tris(8-quinolinolato)aluminum(III)]

[0097] CO-2: Magnesium bisoxine [alias, bis(8quinolinolato)magnesium(II)]

[0098] CO-3: Bis[benzo{f}-8-quinolinolato]zinc (II)

[0099] CO-4: Bis(2-methyl-8-quinolinolato)aluminum(III)-μ-oxo-bis(2-methyl-8-quinolinolato) aluminum(III)

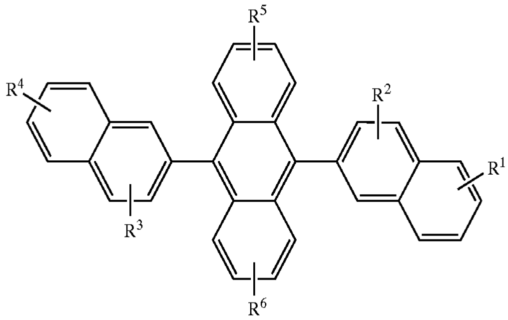
[0100] CO-5: Indium trisoxine [alias, tris(8-quinolinolato)indium]

[0101] CO-6: Aluminum tris(5-methyloxine) [alias, tris(5-methyl-8-quinolinolato)aluminum(III)]

[0102] CO-7: Lithium oxine [alias, (8-quinolinolato)lithium(I)]

[0103] Derivatives of 9,10-di-(2-naphthyl)anthracene (Formula F) constitute one class of useful hosts capable of supporting electroluminescence, and are particularly suitable for light emission of wavelengths longer than 400 nm, e.g., blue, green, yellow, orange or red.

F



[0104] wherein: R^1, R^2, R^3, and R^4 represent one or more substituents on each ring where each substituent is individually selected from the following groups:

[0105] Group 1: hydrogen, or alkyl of from 1 to 24 carbon atoms;

[0106] Group 2: aryl or substituted aryl of from 5 to 20 carbon atoms;

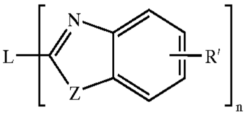
[0107] Group 3: carbon atoms from 4 to 24 necessary to complete a fused aromatic ring of anthracenyl; pyrenyl, or perylenyl;

[0108] Group 4: heteroaryl or substituted heteroaryl of from 5 to 24 carbon atoms as necessary to complete a fused heteroaromatic ring of furyl, thienyl, pyridyl, quinolinyl or other heterocyclic systems;

[0109] Group 5: alkoxylamino, alkylamino, or arylamino of from 1 to 24 carbon atoms; and

[0110] Group 6: fluorine, chlorine, bromine or cyano.

[0111] Benzazole derivatives (Formula G) constitute another class of useful hosts capable of supporting electroluminescence, and are particularly suitable for light emission of wavelengths longer than 400 nm, e.g., blue, green, yellow, orange or red.



G

[0112] Where:

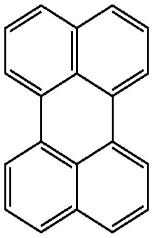
[0113] n is an integer of 3 to 8;

[0114] Z is O, NR or S; and

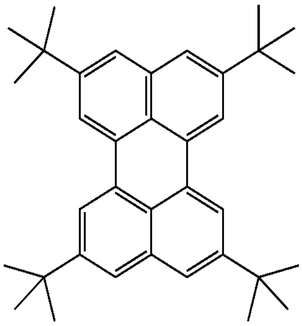
> **[0115]** R' is hydrogen; alkyl of from 1 to 24 carbon atoms, for example, propyl, t-butyl, heptyl, and the like; aryl or heteroatom substituted aryl of from 5 to 20 carbon atoms for example phenyl and naphthyl, furyl, thienyl, pyridyl, quinolinyl and other heterocyclic systems; or halo such as chloro, fluoro; or atoms necessary to complete a fused aromatic ring;
>
> **[0116]** L is a linkage unit consisting of alkyl, aryl, substituted alkyl, or substituted aryl, which conjugately or unconjugately connects the multiple benzazoles together.

[0117] An example of a useful benzazole is 2,2',2"-(1,3,5-phenylene)tris[1-phenyl-1H-benzimidazole].

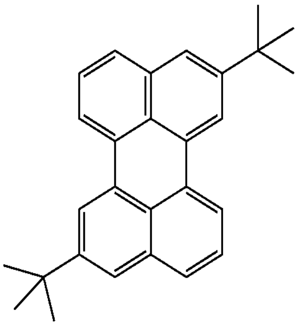
[0118] Desirable fluorescent dopants include derivatives of anthracene, tetracene, xanthene, perylene, rubrene, coumarin, rhodamine, quinacridone, dicyanomethylenepyran compounds, thiopyran compounds, polymethine compounds, pyrilium and thiapyrilium compounds, and carbostyryl compounds. Illustrative examples of useful dopants include, but are not limited to, the following:



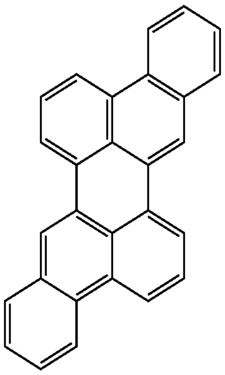
L1



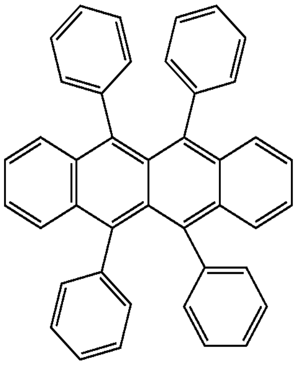
L2



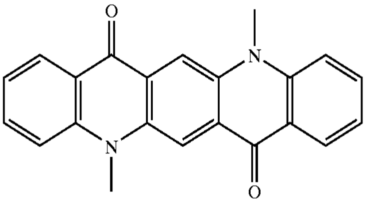
L3



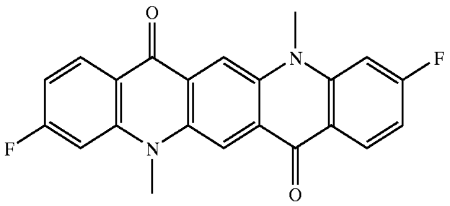
L4



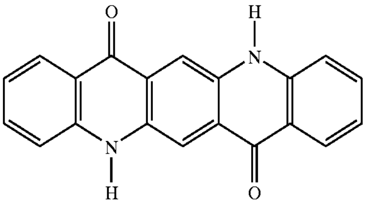
L5



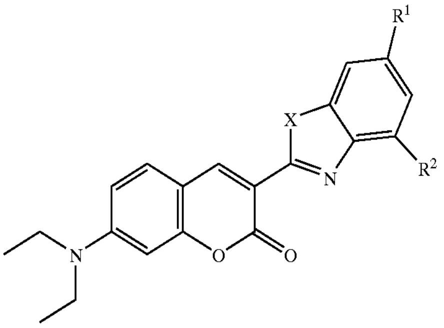
L6



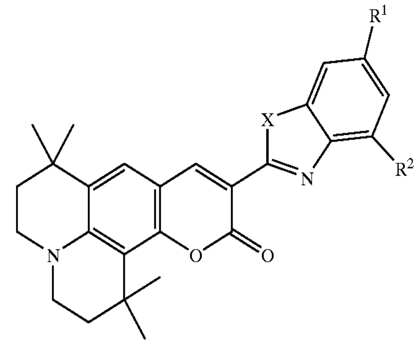
L7



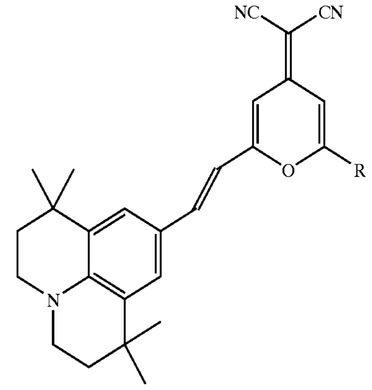
L8



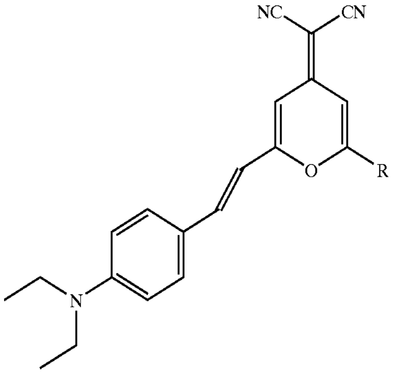
	X	R1	R2
L9	O	H	H
L10	O	H	Methyl
L11	O	Methyl	H
L12	O	Methyl	Methyl
L13	O	H	t-butyl
L14	O	t-butyl	H
L15	O	t-butyl	t-butyl
L16	S	H	H
L17	S	H	Methyl
L18	S	Methyl	H
L19	S	Methyl	Methyl
L20	S	H	t-butyl
L21	S	t-butyl	H
L22	S	t-butyl	t-butyl



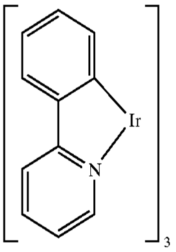
	X	R1	R2
L23	O	H	H
L24	O	H	Methyl
L25	O	Methyl	H
L26	O	Methyl	Methyl
L27	O	H	t-butyl
L28	O	t-butyl	H
L29	O	t-butyl	t-butyl
L30	S	H	H
L31	S	H	Methyl
L32	S	Methyl	H
L33	S	Methyl	Methyl
L34	S	H	t-butyl
L35	S	t-butyl	H
L36	S	t-butyl	t-butyl



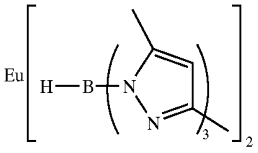
	R
L37	phenyl
L38	methyl
L39	t-butyl
L40	mesityl



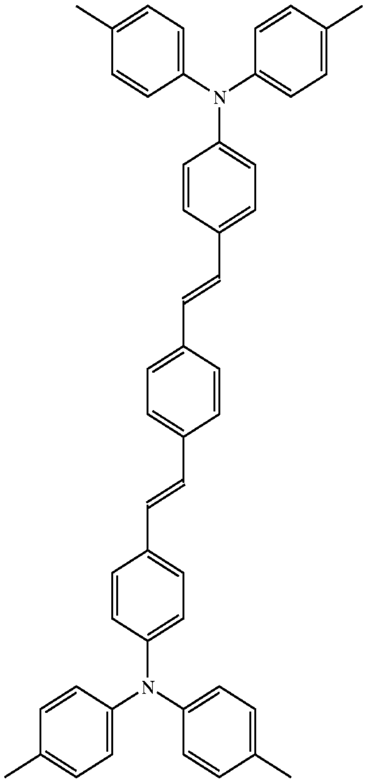
	R
L41	phenyl
L42	methyl
L43	t-butyl
L44	mesityl



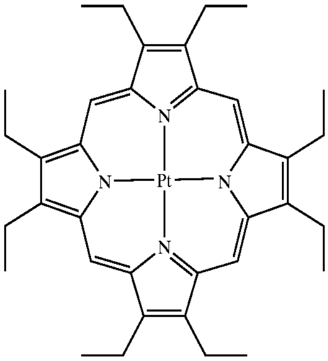
L45



L46



L47



L48

[0119] Other emissive organic materials can be polymeric substances, e.g. polyphenylenevinylene derivatives, dialkoxy-polyphenylenevinylenes, poly-para-phenylene derivatives, and polyfluorene derivatives, as taught by Wolk et al in U.S. Pat. No. 6,194,119 B1 and references therein.

[0120] Donor element **36** is an element coated with one or more coated organic layers that can produce part or all of an OLED device and that can subsequently be transferred in whole or in part such as by thermal transfer. The donor element **36** includes a donor support element. The donor support element has been described by Tang et al in commonly assigned U.S. Pat. No. 5,904,961 and which can be made of any of several materials or combinations of materials which meet at least the following requirements: the donor support element must be sufficiently flexible and possess adequate tensile strength to tolerate coating steps and roll-to-roll or stacked-sheet transport of the support in the practice of the invention. The donor support element must be capable of maintaining the structural integrity during the radiation-to-heat-induced transfer step while pressurized on one side, and during any preheating steps contemplated to remove volatile constituents such as water vapor. Additionally, the donor support element must be capable of receiving on one surface a relatively thin coating of material, and of retaining this coating without degradation during anticipated storage periods of the coated support. Support materials meeting these requirements include, for example, metal foils, plastic foils, and fiber-reinforced plastic foils. While selection of suitable support materials can rely on known engineering approaches, it will be appreciated that certain aspects of a selected support material merit further consideration when configured as a donor support element useful in the practice of the invention. For example, a donor support element can require a multi-step cleaning and surface preparation process prior to coating with material. If the support material is a radiation-transmissive material, the incorporation into a donor support element or onto a surface thereof, of a radiation-absorptive material can be advantageous to more effectively heat the donor support element and to provide a correspondingly enhanced transfer of material from donor element **36** to substrate **30**, when using a flash of radiation from a suitable radiation source such as laser light from a suitable laser. The radiation-absorptive material can include a dye such as the dyes specified in commonly-assigned U.S. Pat. No. 5,578,416, a pigment such as carbon, or a metal such as nickel, chromium, titanium etc. Donor element **36** further includes light-emitting material as described above coated on the donor element. Donor element **36** can be introduced to unitary housing **10** by means of load lock **14** or load lock **16** and transferred by mechanical means to second station **24**. This can occur before, after, or during the introduction of substrate **30**.

[0121] Controlled atmosphere coater **8** also includes third station **26**, which is a means for forming a second electrode over the first and second organic layers of emissive coated substrate **30** coated in first and second stations **20** and **24**. Coating apparatus **54** can represent e.g. one or more heated boats for vaporizing electrode materials. The second electrode is most commonly a cathode. When light emission is through the anode, the cathode material can include nearly any conductive material. Desirable materials have good film-forming properties to ensure good contact with the underlying organic layer, promote electron injection at low voltage, and have good stability. Useful cathode materials often contain a low work function metal (<4.0 eV) or metal alloy. One preferred cathode material is comprised of a Mg:Ag alloy wherein the percentage of silver is in the range of 1 to 20%, as described in U.S. Pat. No. 4,885,221. Another suitable class of cathode materials includes bilayers comprised of a thin layer of a low work function metal or metal salt capped with a thicker layer of conductive metal. One such cathode is comprised of a thin layer of LiF followed by a thicker layer of Al as described in commonly-assigned U.S. Pat. No. 5,677,572. Other useful cathode materials include, but are not limited to, those disclosed in commonly-assigned U.S. Pat. Nos. 5,059,861; 5,059,862, and 6,140,763.

[0122] When light emission is viewed through the cathode, the cathode must be transparent or nearly transparent. For such applications, metals must be thin or one must use transparent conductive oxides, or a combination of these materials. Optically transparent cathodes have been described in more detail in commonly-assigned U.S. Pat.

No. 5,776,623. Cathode materials can be deposited by evaporation, sputtering, or chemical vapor deposition. When needed, patterning can be achieved through many well known methods including, but not limited to, through-mask deposition, integral shadow masking as described in U.S. Pat. No. 5,276,380 and EP 0 732 868, laser ablation, and selective chemical vapor deposition.

[0123] These operations can be simultaneous at the various stations. For example, the substrate **30** can be used in a radiation-induced transfer at second station **24**, while a previously-transferred substrate **30** is being coated at third station **26** and an uncoated substrate **30** is being coated at first station **20**.

[0124] A process control means, e.g. computer **50** can be arranged to control controlled-environment source **12** via data input/output **56**. Robot **22** can be controlled by computer **50** via data input/output **58**. Computer **50** can also be a process control means for controlling in a time sequence the actuation of the first, second, and third coating means, that is first, second, and third stations **20**, **24**, and **26**, respectively. Computer **50** also controls the actuable robot control means, that is robot **22**, and the actuable radiation means, that is laser **38**.

[0125] Although **FIG. 1** shows a system including three stations, this invention is not limited to three stations. For example, a fourth station can be provided in the controlled environment of unitary housing **10** for pretreating substrate **30** before being coated in first station **20**. In a pretreatment step, substrate **30** can be cleaned or otherwise prepared for subsequent processing steps.

[0126] In another embodiment, a fourth (or a fifth) station can be provided in the controlled environment of unitary housing **10** for encapsulating the OLED device after forming a second electrode in third station **26**. Most OLED devices are sensitive to moisture or oxygen, or both, so they are commonly sealed in an inert atmosphere such as nitrogen or argon, along with a desiccant such as alumina, bauxite, calcium sulfate, clays, silica gel, zeolites, alkaline metal oxides, alkaline earth metal oxides, sulfates, or metal halides and perchlorates. Methods for encapsulation and desiccation include, but are not limited to, those described in commonly-assigned U.S. Pat. No. 6,226,890. In addition, barrier layers such as SiOx, Teflon, and alternating inorganic/polymeric layers are known in the art for encapsulation.

[0127] In another embodiment, a fourth station can be provided in the controlled environment of controlled atmosphere coater **8** for coating additional organic layers on substrate **30** after forming an emissive layer in second station **24**. Such additional layers can include electron-transporting layers and electron-injecting layers.

[0128] Preferred electron-transporting materials for use in organic EL devices of this invention are metal chelated oxinoid compounds, including chelates of oxine itself (also commonly referred to as 8-quinolinol or 8-hydroxyquinoline). Such compounds help to inject and transport electrons and exhibit both high levels of performance and are readily fabricated in the form of thin films. Exemplary of contemplated oxinoid compounds are those satisfying structural formula (E), previously described.

[0129] Other electron-transporting materials include various butadiene derivatives as disclosed in commonly-assigned U.S. Pat. No. 4,356,429 and various heterocyclic optical brighteners as described in commonly-assigned U.S. Pat. No. 4,539,507. Benzazoles satisfying structural formula (G) are also useful electron transporting materials.

[0130] Other electron-transporting materials can be polymeric substances, e.g. polyphenylenevinylene derivatives, poly-para-phenylene derivatives, polyfluorene derivatives, polythiophenes, polyacetylenes, and other conductive polymeric organic materials such as those listed in U.S. Pat. No. 6,221,553 B1 and references therein.

[0131] In some instances, a single layer can serve the function of supporting both light emission and electron transportation, and will therefore include emissive material and electron transporting material.

[0132] An electron-injecting layer can also be present between the cathode and the electron-transporting layer. Examples of electron-injecting materials include alkali halide salts, such as LiF mentioned above.

[0133] **FIG. 2** illustrates in another embodiment of this invention a system **100** that combines radiation thermal transfer deposition with conventional deposition techniques such as linear source evaporation with or without shadow masks, as well as with other processes, under a controlled environment for making OLED display devices. System **100** includes a first cluster **105** and second cluster **180**. First cluster **105** includes a first robot **140** and the surrounding stations. Second cluster **180** includes a second robot **150** and the surrounding stations. The nature of the surrounding stations will be further described. It will be evident to those skilled in the art that a variety of embodiments of system **100** are possible. For example, the entirety of system **100** can be enclosed in a controlled atmosphere coater as has already been described. In another embodiment, each station can be an individual controlled atmosphere coater, in which case system **100** includes first cluster **105** of controlled atmosphere coaters wherein first robot **140** selectively positions substrate **30** in the appropriate controlled atmosphere coater, and second cluster **180** of controlled atmosphere coaters wherein second robot **150** selectively positions substrate **30** in the appropriate controlled atmosphere coater. In another embodiment, first cluster **105** can be contained in a first vacuum chamber and second cluster **180** can be enclosed in a controlled environment coater or a second vacuum chamber.

[0134] System **100** includes a loading station **110** that includes an appropriate set of robotics for automatically sorting and inserting both donor elements **36** and substrates **30**. Loading station **110** maintains a moisture-free environment and is further capable of being pumped down from atmospheric pressure to a vacuum condition that is appropriate for subsequent processing steps. In one embodiment, loading station **110** is a vacuum transport vessel that is capable of motion between the desired preprocessing stages, such as the one in which the donor elements **36** are precoated with the radiation-absorbing layer, to system **100**, at which point loading station **110** can be docked to system **100**.

[0135] The first robot **140** is disposed with respect to the elements of system **100** such that it facilitates the time-efficient transport of donor elements **36** and substrates **30** throughout the processing chambers while minimizing operator interface. In one embodiment, first robot **140** includes five central sets of robotics, each of which includes a docking station, which are implemented to facilitate the transport of donor elements **36** and substrates **30** throughout the chambers of system **100**.

[0136] System **100** can include a first station **130**, in which an organic layer such as a continuous hole-transporting layer can be coated atop the substrate **30** or the donor elements **36** using any of a variety of conventional deposition techniques, such as a linear evaporation source; a third station **125**, in which an organic layer such as a continuous electron-transporting layer can be coated atop substrate **30** or donor elements **36** using any of a variety of conventional deposition techniques, such as a linear evaporation source; and a fourth station **120**, in which electrodes such as transparent indium-tin-oxide (ITO) anodes and metallic cathodes can be separately disposed onto substrate **30**, all of which are included in first cluster **105**. In an alternate embodiment, first station **130** and third station **125** can be radiation thermal transfer stations in which the substrate **30** is patterned on a subpixel basis rather than continuously coated. System **100** can further include an appropriate pretreatment station **115**, which can also be called a fifth station, in which the substrates **30** or the donor elements **36** can be cleaned or otherwise prepared for subsequent processing steps.

[0137] System **100** further includes an emissive layer coating station **135**, in which the donor elements **36** are coated with red, green, or blue organic material that is to be subsequently transferred via radiation thermal transfer to the substrate **30** to form the emissive layer. System **100** further includes a pass-through **145** that is a transport chamber that maintains a controlled environment and the second robot **150** that is another set of robotics disposed with respect to the elements of system **100** such that it facilitates the time-efficient transport of donor elements **36** and substrates **30** throughout the processing chambers while minimizing operator interface. System **100** further includes an orientation station **155** that is a set of robotics designed to appropriately align substrates **36** with donor elements **36** in preparation for radiation thermal transfer. Orientation station **155** is sometimes necessary due to the fact that the deposition of layers prior to radiation thermal transfer occurs on the bottoms of the donor elements **36** and the substrates **30**. The coated sides of donor elements **36** and substrates **30** must face one another for radiation thermal transfer to occur. In an alternate embodiment, either donor elements **36** or substrates **30** can receive coatings from the top or both donor sheets and substrates can receive coatings from the side, in which case orientation station **155** can be eliminated.

[0138] System **100** further includes a second station **160**, in which emissive layer material is transferred from the donor elements **36** to the substrates **30**, as well as a vibration isolation element **165**, in which vibrations from the other elements of the system **100** are damped to minimize vibrations that can decrease radiation thermal transfer location accuracy. Vibration isolation can be desired if accurate placement of the radiation thermal transfer process is required, such as in full color pixilated devices. Vibration isolation can be achieved by any number of known active or passive vibration isolation methods. System **100** can further include an encapsulation station **170**, in which the substrate **30**, having all the desirable coatings, is encapsulated and environmentally sealed to form an OLED panel. Finally, system **100** includes an unloading station **175**, in which the encapsulated OLED panel is withdrawn from manufacturing cell. In one embodiment, unloading station **175** is not under vacuum conditions, since the encapsulation layer protects the OLED panel.

[0139] In operation, system **100** maintains a controlled environment while combining all necessary processes for the mixed-mode manufacture of OLED display devices that includes radiation thermal transfer emissive layer deposition. Substrates **30** and donor elements **36** are inserted into system **100** at loading station **110**. In one example, two substrates **30** and six donor elements **36** are loaded at a time into loading station **110** and into system **100**. Loading station **110** sorts the substrates and donor sheets and, via first robot **140**, transfers the substrates **30** and donor elements **36** to the appropriate next chamber. Donor elements **36**, having a previously coated radiation-absorbing layer and optional anti-reflecting layer, are transferred to emissive layer coating station **135**, in which a red, green, or blue emissive organic coating is deposited. Donor elements **36** are transferred through pass-through **145** via first robot **140**, and into second station **160** via second robot **150** to await the radiation thermal transfer process.

[0140] Substrates **30** are transferred via first robot **140** to pretreatment station **115**, in which a pretreatment process occurs. First robot **140** then transfers substrates **30** to fourth station **120**, in which an anode is applied. First robot **140** next transfers substrates **30** to first station **130**, in which an organic hole-transporting layer is applied via a conventional deposition process such as linear evaporation. First robot **140** subsequently transfers substrates **30** to pass-through **145**, at which point the substrates **30** are passed to second robot **150**, which inserts the substrates **30** into second station **160**. Prior to insertion into second station **160**, either the substrates **30** or the donor elements **36** can be reoriented by orientation station **155**, which orients substrates **30** and donor elements **36** such that their coated sides are facing one another in preparation for radiation thermal transfer. Once in second station **160**, the donor elements **36** and substrates **30** are placed in a material transferring relationship, that is, in close proximity or in contact with one another, e.g., with a gap of between 0 and 10 microns therebetween. A radiation beam is swept and modulated across the donor element **36** in an appropriate sweep pattern, impinging through the support of the donor element **36**, and is absorbed within the radiation-absorbing layer included atop the support. The conversion of the radiation beam's energy to heat within the radiation-absorbing layer transfers the organic coating atop the radiation-absorbing layer and thereby transfers the organic material in a desired subpixel pattern to substrate **30**, producing a red, green, or blue subpixel array atop substrate **30**. Two more radiation thermal transfer processes occur within second station **160** to the same substrate **30** using different color donor elements **36** to achieve the other two color subpixel arrays. Alternately, three separate radiation thermal transfer chambers can be included, as is described in reference to **FIG. 3**.

[0141] Upon completion of the deposition of the red, green, and blue emitting subpixel arrays that form the emissive layer atop substrate **30**, substrate **30** is transferred via second robot **150** to pass-through **145**, at which point substrates **30** are passed to first robot **140** and transferred to third station **125**, in which a continuous electron-transporting layer is applied to substrates **30** via a conventional deposition process such as linear evaporation. First robot **140** next passes substrates **30** to fourth station **120**, in which a metallic cathode is applied atop substrates **30**. First robot **140** subsequently transfers the coated substrates **30** back to pass-through **145**, at which point second robot **150** transfers coated substrates **30** to encapsulation station **170**, in which substrates **30** receive a coating that environmentally seals them. Second robot **150** subsequently transfers substrates **30** to unloading station **175**, at which point the finished OLED devices are removed system **100** to await post-processing steps, for example segmenting into individual displays.

[0142] Each of the chambers of system **100**, while shown as if physically attached, can be connected by a vacuum transport chamber or translating vessel that maintains a controlled environment, defined as containing less than 1 torr partial pressure of water, less than 1 torr partial pressure of an oxidizing gas, or both. At no time during the manufacture of the OLED display device within system **100** is a non-controlled environment introduced to the donor elements **36** or the substrates **30**. Any differences in vacuum pressures necessitated by consecutive processing chambers are achieved by an appropriate vacuum transport vessel that can be undocked from a chamber, pumped down to achieve the desired vacuum pressure, and docked to the next processing chamber.

[0143] **FIG. 3** illustrates a system **200** for an increased throughput as opposed to the more typical system **100**. System **200** includes a radiation thermal transfer station **205** including three separate radiation thermal transfer substations **238**, **260**, and **284** for separately positioning at least three different donor element **36** in material transferring relationship with substrates **30** to form different emissive layers on the substrate **30** by separately depositing the red, green, and blue subpixel arrays, respectively, atop substrates **30**. System **200** includes a robot **210** that serves: a pair of substrate loading docks **212** and **214** that are vacuum transport vessels that dock to system **200**; a deposition station **216**, in which a continuous hole-transporting layer coating is deposited atop substrates **30** using any of a variety of conventional deposition techniques, such as a linear evaporation source; a heat treatment station **218**; an orientation station **220**; and a buffer **222**. Robot **210** includes means for positioning a substrate **30** having an electrode in a first station, e.g. deposition station **216**, which is a means for coating one or more organic layer(s) over substrate **30**.

[0144] System **200** further includes a robot **224** for loading donor elements **36**. Robot **224** serves: a pair of donor element loading docks **226** and **228** that are vacuum transport vessels that dock to system **200**; an optional cleaning station **230** that pre-cleans the donor elements **36**; an organic deposition station **232** that deposits red emissive organic material onto the donor elements **36** for subsequent radiation thermal transfer onto substrates **30**; and buffer **234**. System **200** further includes a robot **236** that serves: radiation thermal transfer substation **238**, in which red emissive subpixels are deposited from the red emissive donor elements **36** to the substrates **30**; a pair of donor unloading stations **240** and **242** at which the spent donor elements **36** are withdrawn from system **200**; buffers **222**; **234**; and **244**. Together, robot **210** and robot **236** comprise an actuable robot control means effective when actuated for grasping and removing substrate **30** from deposition station **216** and positioning coated substrate **30** into a second station, e.g. radiation thermal transfer substation **238**, in material transferring relationship with a donor element **36** that includes emissive organic materials. Radiation thermal transfer substation **238** includes an actuable radiation means effective when actuated for applying radiation to donor element **36** to selectively transfer organic material from donor element **36** to substrate **30** to form an emissive layer on coated substrate **30**.

[0145] System **200** further includes a robot **246** for loading donor elements **36**. Robot **246** serves: a pair of donor element loading docks **248** and **250** that are vacuum transport vessels that dock to system **200**; an optional cleaning station **252** that pre-cleans the donor elements **36**; an organic deposition station **254** that deposits green emissive organic material onto the donor elements **36** for subsequent radiation thermal transfer onto substrates **30**; and a buffer **256**. System **200** further includes a robot **258** that serves: a radiation thermal transfer substation **260**, in which green emissive subpixels are deposited from the green emissive donor elements **36** to substrates **30**; a pair of donor unloading stations **262** and **264**, at which the spent donor elements **36** are withdrawn from system **200**; buffers **244**; **256**; and **268**. Together, robot **236** and robot **258** comprise an actuable robot control means effective when actuated for grasping and removing substrate **30** from radiation thermal transfer station **238** and positioning coated substrate **30** into radiation thermal transfer substation **260**, in material transferring relationship with a donor element **36** that includes emissive organic materials. Radiation thermal transfer substation **260** includes an actuable radiation means effective when actuated for applying radiation to donor element **36** to selectively transfer organic material from donor element **36** to substrate **30** to form an emissive layer on coated substrate **30**.

[0146] System **200** further includes a robot **270** for loading donor elements **36**. Robot **270** serves: a pair of donor element loading docks **272** and **274** that are vacuum transport vessels that dock to system **200**; an optional cleaning station **276** that pre-cleans the donor elements **36**; an organic deposition station **278** that deposits blue emissive organic material onto the donor elements **36** for subsequent radiation thermal transfer onto substrates **30**; and a buffer **280**. System **200** further includes a robot **282** that serves: radiation thermal transfer substation **284**, in which blue emissive subpixels are deposited from the blue emissive donor elements **36** to substrates **30**; a pair of donor unloading stations **286** and **288**, at which the spent donor elements **36** are withdrawn from system **200**; buffers **268**; **280**; and **290**. Together, robot **258** and robot **282** comprise an actuable robot control means effective when actuated for grasping and removing substrate **30** from radiation thermal transfer station **260** and positioning coated substrate **30** into radiation thermal transfer substation **284**, in material transferring relationship with a donor element **36** that includes emissive organic materials. Radiation thermal transfer substation **284** includes an actuable radiation means effective when actuated for applying radiation to donor element **36** to selectively transfer organic material from donor element **36** to substrate **30** to form an emissive layer on coated substrate **30**.

[0147] Lastly, system **200** further includes a robot **292** for unloading substrate **30**. Robot **292** serves: a pair of substrate unloading docks **298** and **299** that are vacuum transport vessels that dock to system **200**; a deposition station **295**, in which a continuous electron-transporting layer coating is deposited atop substrates **30** using any of a variety of conventional deposition techniques, such as a linear evaporation source; an optional deposition station **296** for depositing an electron-injecting layer such as copper phthalocyanine (CuPC); an electrode coating station **297**; an orientation station **294**; and buffer **290**. Together, robot **282** and robot **292** comprise an actuable robot control means effective when actuated for grasping and removing emissive coated substrate **30** from radiation thermal transfer substation **284** and positioning emissive coated substrate **30** into a deposition station **295**, which is a means for coating one or more second organic layer(s) over emissive layer coated substrate **30**.

[0148] Buffers **222, 234, 244, 256, 268, 280**, and **290** can be pass-throughs or vacuum transport vessels that maintain a controlled environment and provide storage space to accumulate substrates **30** or donor elements **36** in the event that a halt in production occurs downstream.

[0149] In system **200**, the individual stations are comprised of clusters of controlled atmosphere coaters. For example, a first station for coating organic layers comprises a cluster of controlled atmosphere coaters surrounding robot **210**. A second station for radiation thermal transfer comprises a cluster of controlled atmosphere coaters surrounding robots **236, 258**, and **282**. A third station for coating organic layers comprises a clusters of controlled atmosphere coaters surrounding robot **292**.

[0150] In operation, substrates **30** are loaded into system **200** at substrate loading docks **212** and **214**. Robot **210** transfers a substrate **30** to deposition station **216**, in which a hole-transporting layer is deposited on the substrate. Robot **210** then transfers substrate **30** to heat treatment station **218**, in which substrate **30** is heated. Robot **210** next transfers substrate **30** to orientation station **220**, at which the substrate is oriented appropriately for subsequent radiation thermal transfer. Robot **210** then passes substrate **30** to buffer **222**, in which the substrate is passed to robot **236**. Concurrently, robot **224** passes a red-emissive coated donor element **36** through buffer **234** to robot **236**. Robot **236** mates the donor element **36** to the substrate **30**. Robot **236** transfers the donor element **36** and the substrate **36** to radiation thermal transfer substation **238**, in which emissive material is transferred from the donor element **36** to the substrate **30** in the pattern of an array of red subpixels. The spent donor elements **36** are withdrawn from system **200** by donor unloading stations **240** and **242**. Robot **236** next passes substrate **30** to buffer **244**, in which it is passed to robot **258**. Concurrently, robot **246** passes a green-emissive coated donor element **36** through buffer **256** to robot **258**. Robot **258** mates the donor element **36** to substrate **30**. Robot **258** transfers the donor element **36** and the substrate **30** to radiation thermal transfer substation **260**, in which emissive material is transferred from the donor element **36** to the substrate **30** in the pattern of an array of green subpixels. The spent donor elements **36** are withdrawn from system **200** by donor unloading stations **262** and **264**. Robot **258** next passes substrate **30** to buffer **268**, in which it is passed to robot **282**. Concurrently, robot **270** passes a blue-emissive coated donor element **36** through buffer **280** to robot **282**. Robot **282** mates the donor element **36** to substrate **30**. Robot **282** transfers the donor element **36** and substrate **30** to radiation thermal transfer substation **284**, in which emissive material is transferred from the donor element **36** to the substrate **30** in the pattern of an array of blue subpixels. The spent donor elements **36** are withdrawn from system **200** by donor unloading stations **286** and **288**. Robot **282** next passes substrate **30** to buffer **290**, in which it is passed to robot **292**. Robot **292** transfers substrate **30** to orientation station **294**, at which point the substrate is oriented appropriately for deposition of an electron-transporting layer. Robot **292** next transfers substrate **30** to deposition station **295**, in which an electron-transporting layer is deposited. Optionally, robot **292** next transfers substrate **30** to deposition station **296**, in which an electron-injecting layer such as a copper phthalocyanine layer is deposited. Robot **292** next transfers substrate **30** to electrode coating station **297** in which an electrode layer is deposited. Robot **292** next transfers substrate **30** to substrate unloading dock **298** or **299**, at which point substrate **30** is withdrawn from system **200** to undergo post-processing steps, such as deposition of an encapsulation layer.

[0151] Concurrently to the aforementioned processing of substrate **30**, robot **224** continuously inserts donor elements **36** into system **200** from donor element loading docks **226** and **228**. Robot **224** transfers a donor element **36** from donor element loading dock **226** or **228** to optional cleaning station **230**, in which the donor element **36** is pre-cleaned. Robot **224** then transfers the donor element **36** to organic deposition station **232**, in which red-emissive organic material is deposited atop the donor element **36**, which is to be subsequently transferred via radiation thermal transfer to substrate **36** to form the array of red subpixels. Robot **224** next transfers donor element **36** to buffer **234**, in which it is passed to robot **236**. Similarly and concurrently, robot **246** continuously inserts donor elements **36** into system **200** from donor element loading docks **248** and **250**. Robot **246** transfers a donor element **36** from donor element loading dock **248** or **250** to optional cleaning station **252**, in which donor element **36** is pre-cleaned. Robot **246** then transfers the donor element **36** to organic deposition station **254**, in which green-emissive organic material is deposited atop the donor element **36**, which is to be subsequently transferred via radiation thermal transfer to substrate **30** to form the array of green subpixels. Robot **246** next transfers donor element **36** to buffer **256**, in which it is passed to robot **258**. Similarly and concurrently, robot **270** continuously inserts donor elements **36** into system **200** from donor element loading docks **272** and **274**. Robot **270** transfers a donor element **36** from donor element loading dock **272** or **274** to optional cleaning station **276**, in which the donor element **36** is pre-cleaned. Robot **270** then transfers the donor element **36** to organic deposition station **278**, in which blue-emissive organic material is deposited atop the donor element **36**, which is to be subsequently transferred via radiation thermal transfer to substrate **30** to form the array of blue subpixels. Robot **270** next transfers donor element **36** to buffer **280**, in which it is passed to robot **282**.

[0152] The inclusion of a pair of substrate loading docks **212** and **214** enables undisrupted manufacturing by allowing substrates **30** to be loaded from substrate loading dock **212** until empty, at which point substrates **30** are loaded from substrate loading dock **214** while substrate loading dock **212** is replenished. For similar throughput reasons, pairs of donor element loading docks **226** and **228, 248** and **250**, and **272** and **274**; pairs of donor unloading stations **240** and **242**,

262 and **264**, and **286** and **288**; and a pair of substrate unloading docks **298** and **299** are included in system **200**.

[0153] **FIG. 4** illustrates a dual system **300** in which donor elements **36** and substrates **30** are treated separately. A substrate deposition cluster **312** includes three separate radiation thermal transfer stations **342, 344,** and **346**, each of which performs radiation thermal transfer of all three color subpixels to separate substrates **30** to provide a throughput commensurate with system **200**. Substrate deposition cluster **312** further includes a robot **326** that serves: a pair of substrate loading docks **328** and **330** that are controlled-environment transport vessels that dock to substrate deposition cluster **312**; an organic deposition station **332** in which a continuous hole-transporting layer coating is deposited atop substrates **30** using any of a variety of conventional deposition techniques, such as a linear evaporation source; and an orientation station **334**. Substrate deposition cluster **312** further includes a central robot **336** that serves radiation thermal transfer stations **342, 344,** and **346**, as well as a pair of donor unloading stations **338** and **340**, at which the spent donor elements **36** are withdrawn from substrate deposition cluster **312**. Substrate deposition cluster **312** further includes a robot **352** that serves: a pair of substrate unloading docks **354** and **356** that are controlled-environment transport vessels that dock to substrate deposition cluster **312**; an organic deposition station **350**, in which a continuous electron-transporting layer coating is deposited atop substrates **30** using any of a variety of conventional deposition techniques, such as a linear evaporation source; and an orientation station **348**.

[0154] In addition to substrate deposition cluster **312**, dual system **300** further includes a donor preparation cluster **310** that prepares donor elements **36** for the subsequent radiation thermal transfer processes that occur in substrate deposition cluster **312**. Donor preparation cluster **310** includes a central robot **314** that serves: a pair of donor element loading and unloading docks **316** and **318** that are controlled-environment transport vessels that dock to donor preparation cluster **310** and each of which has loading and unloading functionality; an organic deposition station **320** that deposits red-emissive organic material onto donor elements **36** for subsequent radiation thermal transfer onto substrates **30**; an organic deposition station **322** that deposits green-emissive organic material onto a separate series of donor elements for subsequent radiation thermal transfer onto substrates **30**; and an organic deposition station **324** that deposits blue-emissive organic material onto a separate series of donor elements **36** for subsequent radiation thermal transfer onto substrates **30**.

[0155] Donor elements **36** that are prepared in donor preparation cluster **310** can be transferred from donor element loading docks **316** and **318** to substrate deposition cluster **312** at donor unloading stations **338** and **340** using a transport vessel that maintains a suitable controlled environment and is capable of docking to donor preparation cluster **310** and substrate deposition cluster **312**.

[0156] The inclusion of the pair of substrate loading docks **328** and **330** enables undisrupted manufacturing by allowing substrates **30** to be loaded from substrate loading dock **328** until empty, at which point substrates **30** are loaded from substrate loading dock **330** while substrate loading dock **328** is replenished. For similar throughput reasons, the pair of donor element loading docks **316** and **318**, the pair of donor unloading stations **338** and **340**, and the pair of substrate unloading docks **354** and **356** are included in dual system **300**.

[0157] In another embodiment, a plurality of donor preparation clusters **310** can prepare donor elements **36** for substrate deposition cluster **312**.

[0158] **FIG. 5** illustrates a system **400** in which a central robot **420** is fed by a plurality of lines, three of which prepare the different color emissive donor elements **36**; three of which include a radiation thermal transfer station **448**, **454**, and **460**, each of which performs radiation thermal transfer of all three color subpixels to separate substrates **30**; one of which prepares substrate **30** for radiation thermal transfer; and one of which processes substrates **30** subsequent to radiation thermal transfer. System **400** includes a robot **410** that serves: a pair of substrate loading docks **412** and **414** that are controlled environment transport vessels that dock to system **400**; an organic deposition station **416** in which a continuous hole-transporting layer coating is deposited atop substrates **30** using any of a variety of conventional deposition techniques, such as a linear evaporation source; and an orientation station **418**.

[0159] System **400** further includes a robot **422** that serves: a donor element loading dock (DL) **424** that is a controlled environment transport vessel that docks to system **400**, and an organic deposition station **426** that deposits red-emissive organic material onto the donor elements **36** for subsequent radiation thermal transfer onto substrates **30**. Robot **428** transfers red-emissive donor elements **36** from organic deposition station **426** to robot **420**. System **400** further includes a robot **430** that serves: a donor element loading dock **432** that is a controlled environment transport vessel that docks to system **400**, and an organic deposition station **434** that deposits green-emissive organic material onto the donor elements **36** for subsequent radiation thermal transfer onto substrates **30**. A robot **436** transfers green-emissive donor sheets from organic deposition station **434** to robot **420**. System **400** further includes a robot **438** that serves: a donor element loading dock **440** that is a controlled environment transport vessel that docks to system **400**, and an organic deposition station **442** that deposits blue-emissive organic material onto the donor elements **36** for subsequent radiation thermal transfer onto substrates **30**. Robot **444** transfers blue-emissive donor sheets from organic deposition station **442** to robot **420**.

[0160] System **400** further includes a robot **446** that serves radiation thermal transfer station **448** and a donor unloading station **450**, at which spent donor elements **36** are withdrawn from system **400**; a robot **452** that serves radiation thermal transfer station **454** and a donor unloading station **456**, at which the spent donor elements **36** are withdrawn from system **400**; and a robot **458** that serves radiation thermal transfer station **460** and a donor unloading station **462**, at which the spent donor elements **36** are withdrawn from system **400**. System **400** further includes a robot **468** that serves: a pair of substrate unloading docks **470** and **472** that are controlled environment transport vessels that dock to system **400**; an organic deposition station **466** in which a continuous electron-transporting layer coating is deposited atop substrates **30** using any of a variety of conventional deposition techniques, such as a linear evaporation source; and an orientation station **464**.

[0161] **FIG. 6** illustrates a system **500** that is a mini-production facility in which a single radiation thermal transfer deposition station **540** is included to perform all three color subpixel depositions. System **500** includes a robot **510** that serves: a substrate loading dock **512** that is a controlled environment transport vessel that docks to system **500**; an organic deposition station **514** in which a continuous hole-transporting layer coating is deposited atop substrates **30** using any of a variety of conventional deposition techniques, such as a linear evaporation source; a heat treatment station **516**; an orientation station **518**; and a buffer **520**.

[0162] System **500** further includes robot **524** that serves: a donor element loading dock **526** that is a controlled environment transport vessel that docks to system **500**; an optional cleaning station **536** that pre-cleans the donor elements **36**; an organic deposition station **528** that deposits red-emissive organic material onto the donor elements **36** for subsequent radiation thermal transfer onto substrates **30**; an organic deposition station **530** that deposits green-emissive organic material onto the donor elements **36** for subsequent radiation thermal transfer onto substrates **30**; an organic deposition station **532** that deposits blue-emissive organic material onto the donor elements **36** for subsequent radiation thermal transfer onto substrates **30**; an optional organic deposition station **534** for depositing hole-transporting material onto the donor elements **36** for subsequent radiation thermal transfer onto substrates **30**; and a buffer **538**.

[0163] System **500** further includes a robot **522** that serves: a radiation thermal transfer station **540**, in which red-, green-, and blue-emissive organic material is deposited in separate steps from the red-, green-, and blue-emissive coated donor elements **36**, respectively, to substrates **30**; a donor unloading station **542** at which the spent donor elements **36** are withdrawn from system **500**; buffers **520**, **538**, and **544**. Lastly, system **500** includes a robot **546** that serves: a substrate unloading dock **554** that is a controlled environment transport vessel that docks to system **500**; an organic deposition station **550** in which a continuous electron-transporting layer coating is deposited atop substrates **30** using any of a variety of conventional deposition techniques, such as a linear evaporation source; an optional organic deposition station **552** for depositing an electron-injecting layer such as copper phthalocyanine; an orientation station **548**; and buffer **544**.

[0164] **FIG. 7** illustrates a system **600** that uses a continuous roll of donor web rather than discrete framed donor elements **36**. System **600** includes a structure or series of structures for separately positioning at least three different donor elements **36** in material transferring relationship with the substrate **30** to form different emissive layers on the substrate **30**. System **600** includes a substrate loading robot **610** that serves: a pair of substrate loading docks **612** and **614** that are controlled environment transport vessels that dock to system **600**; an organic deposition station **616** in which a continuous hole-transporting layer coating is deposited atop substrates **30** using any of a variety of conventional deposition techniques, such as a linear evaporation source; a heat treatment station **618**; an orientation station **620**; and a substrate conveying means **622** that in one example is a conveyor belt, by which the substrates **30** translate to a red radiation thermal transfer station **628**.

[0165] System **600** further includes a donor web unwind chamber **624** in which a roll of uncoated donor web unwinds; an organic deposition station **626** through which the donor web translates and in which red-emissive organic material is deposited onto the donor web for subsequent radiation thermal transfer onto substrates **30**; radiation thermal transfer station **628**, through which the donor web translates and in which radiation thermal transfer occurs from the red-emissive coated donor web onto substrate **30**; and a donor web rewind chamber **630** in which the spent donor web winds onto a take-up spool.

[0166] System **600** further includes a donor web unwind chamber **634** in which a roll of uncoated donor web unwinds; an organic deposition station **636** through which the donor web translates and in which green-emissive organic material is deposited onto the donor web for subsequent radiation thermal transfer onto substrates **30**; a radiation thermal transfer station **638**, through which the donor web translates and in which radiation thermal transfer occurs from the green-emissive coated donor web onto substrate **30**; and a donor web rewind chamber **640** in which the spent donor web winds onto a take-up spool.

[0167] System **600** further includes a donor web unwind chamber **644** in which a roll of uncoated donor web unwinds; an organic deposition station **646** through which the donor web translates and in which blue-emissive organic material is deposited onto the donor web for subsequent radiation thermal transfer onto substrates **30**; a radiation thermal transfer station **648**, through which the donor web translates and in which radiation thermal transfer occurs from the blue-emissive coated donor web onto substrate **30**; and a donor web rewind chamber **650** in which the spent donor web winds onto a take-up spool.

[0168] System **600** further includes a substrate unloading robot **654** that serves: a pair of substrate unloading docks **660** and **662** that are controlled environment transport vessels that dock to system **600**; an organic deposition station **658** in which a continuous electron-transporting layer coating is deposited atop substrates **30** using any of a variety of conventional deposition techniques, such as a linear evaporation source; and an orientation station **656**. System **600** further includes a substrate conveying means **632**, by which the substrates **30** translate from radiation thermal transfer station **628** to radiation thermal transfer station **638**; a substrate conveying means **642**, by which the substrates **36** translate from radiation thermal transfer station **638** to radiation thermal transfer station **648**; and a substrate conveying means **652**, by which the substrates **30** translate from radiation thermal transfer station **648** to robot **654**.

[0169] In an alternate embodiment of system **600**, substrate **30** can also be supplied in the form of a flexible web. Such a use of a flexible substrate web has been described by Phillips et al in above cited commonly-assigned U.S. patent application Ser. No. 10/224,182.

[0170] Turning now to **FIG. 8**, and referring also to **FIG. 1**, there is shown a block diagram comprising the steps in one embodiment of a method for forming an organic light-emitting device according to the present invention. At the start (Step **700**) of the process, the atmosphere of controlled atmosphere coater **8** is controlled as has been described above, thereby controlling the atmosphere in the first, second, and third stations **20**, **24**, and **26**, and in which robot **22** operates (Step **710**). A substrate **30** having an electrode is positioned at first station **20** (Step **720**). An organic layer, e.g. a hole-transporting layer is then coated over substrate **30** by coating apparatus **34** (Step **730**). Then robot **22** grasps and removes substrate **30** from first station **20** (Step **740**), and positions the coated substrate **30** at second station **24** (Step **750**). Substrate **30** is positioned in a material transferring relationship with donor element **36** that includes emissive organic material. Second station **24** applies radiation, e.g. laser beam **40**, to donor element **36** to selectively transfer organic material, e.g. emissive material from donor element **36** to substrate **30** by radiation thermal transfer to form an organic emissive layer on coated substrate **30** (Step **760**). Then substrate **30** is moved to third station **26** by any of a variety of means, e.g. manually or by the same or another robot (Step **770**). A second electrode is formed in third station **26** over the organic emissive layer(s) of emissive coated substrate **30** (Step **780**), at which point the process ends (Step **790**). As has been described above, various other steps are also possible, e.g. formation of a first electrode if one has not already been included on substrate **30**, formation of an electron-transporting layer, etc.

[0171] Turning now to **FIG. 9**, and referring also to **FIG. 1** and **FIG. 2**, there is shown a block diagram comprising the steps in another embodiment of a method for forming an organic light-emitting device according to the present invention. At the start (Step **800**) of the process, the atmosphere of system **100** is controlled as has been described above, thereby controlling the atmosphere in the first, second, third, and fourth stations **130**, **160**, **125**, and **120**, and in which robots **140** and **150** operate (Step **810**). A substrate **30** having an electrode is positioned at first station **130** (Step **820**). An organic layer, e.g. a hole-transporting layer is then coated over substrate **30** by coating apparatus **34** (Step **830**). Then robot **140** grasps and removes substrate **30** from first station **130** (Step **840**). Robot **140** transfers substrate **30** through pass-through **145** to robot **150**. Robot **150** positions the coated substrate **30** at second station **160** (Step **850**). Substrate **30** is positioned in a material transferring relationship with donor element **36** that includes emissive organic material. Second station **160** applies radiation, e.g. laser beam **40**, to donor element **36** to selectively transfer organic material, e.g. emissive material from donor element **36** to substrate **30** by radiation thermal transfer to form an organic emissive layer on coated substrate **30** (Step **860**). Then robot **150** grasps and removes emissive coated substrate **30** from second station **160** (Step **870**). Robot **150** transfers emissive coated substrate **30** through pass-through **145** to robot **140**. Robot **140** positions emissive coated substrate **30** in third station **125** (Step **880**). At third station **125**, one or more second organic layers, e.g. electron-transporting layer(s), are coated over the emissive layer coated substrate **30** (Step **890**). Then robot **140** grasps and removes emissive coated substrate **30** from third station **125** (Step **900**) and positions the emissive coated substrate **30** in fourth station **120** (Step **910**). A second electrode is formed in fourth station **120** over the organic emissive layer(s) of emissive coated substrate **30** (Step **920**), at which point the process ends (Step **930**). As has been described above, various other steps are also possible, e.g. formation of a first electrode if one has not already been included on substrate **30**, etc.

[0172] The invention has been described in detail with particular reference to certain preferred embodiments thereof, but it will be understood that variations and modifications can be effected within the spirit and scope of the invention.

Parts List

[0173] **8** controlled atmosphere coater

[0174] **10** unitary housing

[0175] **12** controlled environment source

[0176] **14** load lock

[0177] **16** load lock

[0178] **20** first station

[0179] **22** robot

[0180] **24** second station

[0181] **26** third station

[0182] **30** substrate

[0183] **31** grasping means

[0184] **34** coating apparatus

[0185] **36** donor element

[0186] **38** laser

[0187] **40** laser beam

[0188] **46** transparent portion

[0189] **50** computer

[0190] **54** coating apparatus

[0191] **56** data input/output

[0192] **58** data input/output

[0193] **100** system

[0194] **105** first cluster

[0195] **110** loading station

[0196] **115** pretreatment station

[0197] **120** fourth station

[0198] **125** third station

[0199] **130** first station

[0200] **135** emissive layer coating station

[0201] **140** first robot

[0202] **145** pass-through

[0203] **150** second robot

[0204] **155** orientation station

[0205] **160** second station

[0206] **165** vibration isolation element

[0207] **170** encapsulation station

[0208] **175** unloading station

[0209] **180** second cluster

[0210] **200** system

[0211] **205** radiation thermal transfer station

[0212] **210** robot

[0213] **212** substrate loading dock

[0214] **214** substrate loading dock

[0215] **216** deposition station

[0216] **218** heat treatment station

[0217] **220** orientation station

[0218] **222** buffer

[0219] **224** robot

[0220] **226** donor element loading dock

[0221] **228** donor element loading dock

[0222] **230** cleaning station

[0223] **232** organic deposition station

[0224] **234** buffer

[0225] **236** robot

[0226] **238** radiation thermal transfer substation

[0227] **240** donor unloading station

[0228] **242** donor unloading station

[0229] **244** buffer

[0230] **246** robot

[0231] **248** donor element loading dock

[0232] **250** donor element loading dock

[0233] **252** cleaning station

[0234] **254** organic deposition station

[0235] **256** buffer

[0236] **258** robot

[0237] **260** radiation thermal transfer substation

[0238] **262** donor unloading station

[0239] **264** donor unloading station

[0240] **268** buffer

[0241] **270** robot

[0242] **272** donor element loading dock

[0243] **274** donor element loading dock

[0244] **276** cleaning station

[0245] **278** organic deposition station

[0246] **280** buffer

[0247] **282** robot

[0248] **284** radiation thermal transfer substation

[0249] **286** donor unloading station

[0250] **288** donor unloading station

[0251] **290** buffer

[0252] **292** robot

[0253] **294** orientation station

[0254] **295** deposition station

[0255] **296** deposition station

[0256] **297** electrode coating station

[0257] **298** substrate unloading dock

[0258] **299** substrate unloading dock

[0259] **300** system

[0260] **310** donor preparation cluster

[0261] **312** substrate deposition cluster

[0262] **314** robot

[0263] **316** donor element loading dock

[0264] **318** donor element loading dock

[0265] **320** organic deposition station

[0266] **322** organic deposition station

[0267] **324** organic deposition station

[0268] **326** robot

[0269] **328** substrate loading dock

[0270] **330** substrate loading dock

[0271] **332** organic deposition station

[0272] **334** orientation station

[0273] **336** robot

[0274] **338** donor unloading station

[0275] **340** donor unloading station

[0276] **342** radiation thermal transfer station

[0277] **344** radiation thermal transfer station

[0278] **346** radiation thermal transfer station

[0279] **348** orientation station

[0280] **350** organic deposition station

[0281] **352** robot

[0282] **354** substrate unloading dock

[0283] **356** substrate unloading dock

[0284] **400** system

[0285] **410** robot

[0286] **412** substrate loading dock

[0287] **414** substrate loading dock

[0288] **416** organic deposition station

[0289] **418** orientation station

[0290] **420** robot

[0291] **422** robot

[0292] **424** donor element loading dock

[0293] **426** organic deposition station

[0294] **428** robot

[0295] **430** robot

[0296] **432** donor element loading dock

[0297] **434** organic deposition station

[0298] **436** robot

[0299] **438** robot

[0300] **440** donor element loading dock

[0301] **442** organic deposition station

[0302] **444** robot

[0303] **446** robot

[0304] **448** radiation thermal transfer station

[0305] **450** donor unloading station

[0306] **452** robot

[0307] **454** radiation thermal transfer station

[0308] **456** donor unloading station

[0309] **458** robot

[0310] **460** radiation thermal transfer station

[0311] **462** donor unloading station

[0312] **464** orientation station

[0313] **466** organic deposition station

[0314] **468** robot

[0315] **470** substrate unloading dock

[0316] **472** substrate unloading dock

[0317] **500** system

[0318] **510** robot

[0319] **512** substrate loading dock

[0320] **514** organic deposition station

[0321] **516** heat treatment station

[0322] **518** orientation station

[0323] **520** buffer

[0324] **522** robot

[0325] **524** robot

[0326] **526** donor element loading dock

[0327] **528** organic deposition station

[0328] **530** organic deposition station

[0329] **532** organic deposition station

[0330] **534** organic deposition station

[0331] **536** cleaning station

[0332] **538** buffer

[0333] **540** radiation thermal transfer station

[0334] **542** donor unloading station

[0335] **544** buffer

[0336] **546** robot

[0337] **548** orientation station

[0338] **550** organic deposition station

[0339] **552** organic deposition station

[0340] **554** substrate unloading dock

[0341] **600** system

[0342] **610** robot

[0343] **612** substrate loading dock

[0344] **614** substrate loading dock

[0345] **616** organic deposition station

[0346] **618** heat treatment station

[0347] **620** orientation station

[0348] **622** substrate conveying means

[0349] **624** donor web unwind chamber

[0350] **626** organic deposition station

[0351] **628** radiation thermal transfer station

[0352] **630** donor web rewind chamber

[0353] **632** substrate conveying means

[0354] **634** donor web unwind chamber

[0355] **636** organic deposition station

[0356] **638** radiation thermal transfer station

[0357] **640** donor web rewind chamber

[0358] **642** substrate conveying means

[0359] **644** donor web unwind chamber

[0360] **646** organic deposition station

[0361] **648** radiation thermal transfer station

[0362] **650** donor web rewind chamber

[0363] **652** substrate conveying means

[0364] **654** robot

[0365] **656** orientation station

[0366] **658** organic deposition station

[0367] **660** substrate unloading dock

[0368] **662** substrate unloading dock

[0369] **700** block

[0370] **710** block

[0371] **720** block

[0372] **730** block

[0373] **740** block

[0374] **750** block

[0375] **760** block

[0376] **770** block

[0377] **780** block

[0378] **790** block

[0379] **800** block

[0380] **810** block

[0381] **820** block

[0382] **830** block

[0383] **840** block

[0384] **850** block

[0385] **860** block

[0386] **870** block

[0387] **880** block

[0388] **890** block

[0389] **900** block

[0390] **910** block

[0391] **920** block

[0392] **930** block

What is claimed is:

1. A method of making an OLED device comprising, in a controlled environment, the steps of:

a) positioning a substrate having an electrode in a first station and coating one or more first organic layer(s) over the substrate;

b) using a robot to grasp and remove the substrate from the first station and positioning the coated substrate into a second station, in material transferring relationship with a donor element that includes emissive organic material;

c) applying radiation to the donor element to selectively transfer organic material from the donor element to the substrate to form an emissive layer on the coated substrate;

d) forming a second electrode in a third station over the one or more second organic layers of the emissive coated substrate; and

e) controlling the atmosphere in the first, second, and third stations and in which the robot operates so that the water vapor partial pressure is less than 1 torr but greater than 0 torr, or the oxygen partial pressure is less than 1 torr but greater than 0 torr, or both the water vapor partial pressure and the oxygen partial pressure are respectively less than 1 torr but greater than 0 torr.

2. The method of claim 1 further including sequentially positioning the first, second, and third stations in line, and sequentially moving the substrate in line through the different stations.

3. The method of claim 1 further including providing a fourth station in the controlled environment for encapsulating the OLED device after step d).

4. The method of claim 1 further including providing a fourth station for pretreating the substrate prior to step a).

5. The method of claim 1 wherein the first station includes a first vacuum chamber and a structure for applying a hole-transporting material over the substrate.

6. The method of claim 1 wherein the first station includes a first cluster of controlled atmosphere coaters and the one or more robots selectively positions the substrate in the appropriate controlled atmosphere coater.

7. The method of claim 1 further including a unitary housing encompassing the first, second, and third stations and the robot, and having the controlled atmosphere.

8. A method of making an OLED device comprising, in a controlled environment, the steps of:

a) positioning a substrate having an electrode in a first station and coating one or more first organic layer(s) over the substrate;

b) using a robot to grasp and remove the substrate from the first station and positioning the coated substrate into a second station, in material transferring relationship with a donor element that includes emissive organic material;

c) applying radiation to the donor element to selectively transfer organic material from the donor element to the substrate to form an emissive layer on the coated substrate;

d) using the same or a different robot to grasp the substrate and remove the emissive coated substrate from the second station and positioning the emissive coated substrate in a third station, and coating one or more second organic layers over the emissive layer coated substrate;

e) using the same or a different robot to grasp the emissive coated substrate and remove such emissive coated substrate from the third station, and positioning the emissive coated substrate in a fourth station;

f) forming a second electrode in the fourth station over the one or more second organic layers of the emissive coated substrate; and

g) controlling the atmosphere in the first, second, third, and fourth stations and in which the robot(s) operate so that the water vapor partial pressure is less than 1 torr but greater than 0 torr, or the oxygen partial pressure is less than 1 torr but greater than 0 torr, or both the water vapor partial pressure and the oxygen partial pressure are respectively less than 1 torr but greater than 0 torr.

9. The method of claim 8 further including sequentially positioning the first, second, third, and fourth stations in line, and sequentially moving the substrate in line through the different stations, and wherein the second station includes a structure for separately positioning at least three different donor elements in material transferring relationship with the substrate to form different emissive layers on the substrate.

10. The method of claim 8 further including providing a fifth station in the controlled environment for encapsulating the OLED device after step g).

11. The method of claim 8 further including providing a fifth station for pretreating the substrate prior to step a).

12. The method of claim 8 wherein the first station includes a first vacuum chamber and a structure for applying a hole-transporting material over the substrate.

13. The method of claim 8 wherein the third station includes a second vacuum chamber and a structure for applying an electron-transporting material over the emissive layer.

14. The method of claim 8 wherein the first station includes a first cluster of controlled atmosphere coaters and the one or more robots selectively positions the substrate in the appropriate controlled atmosphere coater.

15. The method of claim 14 wherein the third station is either a second cluster of controlled atmosphere coaters or is included in the first cluster.

16. The method of claim 8 further including a unitary housing encompassing the first, second, third, and fourth stations and the robots, and having the controlled atmosphere.

17. A system for making, in a controlled environment, an OLED device comprising:

a) means for positioning a substrate having an electrode in a first station and coating one or more first organic layer(s) over the substrate;

b) first actuable robot control means effective when actuated for grasping and removing the substrate from the first station and positioning the coated substrate into a second station, in material transferring relationship with a donor element that includes emissive organic material;

c) actuable radiation means effective when actuated for applying radiation to the donor element to selectively transfer organic material from the donor element to the substrate to form an emissive layer on the coated substrate;

d) second actuable robot control means effective when actuated for grasping and removing the emissive coated substrate from the second station and positioning the emissive coated substrate in a third station, and coating means effective when actuated for coating one or more second organic layers over the emissive layer coated substrate;

e) third actuable robot control means effective when actuated for grasping and removing such emissive coated substrate from the third station, and positioning the emissive coated substrate in a fourth station;

f) means for forming a second electrode over the one or more second organic layers of the emissive coated substrate; and

g) process control means for controlling in a time sequence the actuation of the first, second, and third coating means and the actuable robot control means, and the actuable radiation means; and

h) means for controlling the atmosphere in the first, second, third, and fourth stations and in which the robot(s) operate so that the water vapor partial pressure is less than 1 torr but greater than 0 torr, or the oxygen partial pressure is less than 1 torr but greater than 0 torr, or both the water vapor partial pressure and the oxygen partial pressure are respectively less than 1 torr but greater than 0 torr.

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专利名称(译)	具有至少一个用于制造OLED显示器的热转移站的方法和系统		
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CPC分类号	C23C14/28 C23C14/568 H01L21/67161 H01L21/67167 H01L21/67184 H01L51/001 H01L51/0013 H01L51/0052 H01L51/0059 H01L51/0062 H01L51/0077 H01L51/0081 H01L51/0084 H01L51/0085 H01L51/0089 H01L51/56 H05B33/10		
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摘要(译)

在受控环境中制造OLED器件包括在第一工位中定位具有电极的基板并涂覆一个或多个第一有机层;使用机器人从第一工位抓住并移除基板，并将涂覆的基板定位到第二工位，其中供体元件包括发光有机材料;施加辐射以选择性地将有机材料从供体元件转移到基板上以形成发光层;在第三站中形成第二电极;并控制站内的气氛，使水蒸气分压小于1托但大于0托，或氧分压小于1托但大于0托，或水蒸气分压和氧分压分别小于1托但大于0托。