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(71) Applicant *(for all designated States except US)*: **E.I. DUPONT DE NEMOURS AND COMPANY** [US/US]; 1007 MARKET STREET, WILMINGTON, Delaware 19898 (US).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **CARCIA, Peter, Francis** [US/US]; 3413 Sweetbriar Road, Wilmington, Delaware 19810 (US). **MCLEAN, Robert, Scott** [US/US]; 208 Eileen's Way, Hockessin, Delaware 19707 (US).

(74) Agent: SIEGELL, Barbara, C.; E. I. Du Pont de Nemours and Company, Legal Patemt Records Center, 4417 Lancaster Pike, Wilmington, Delaware 19805 (US).

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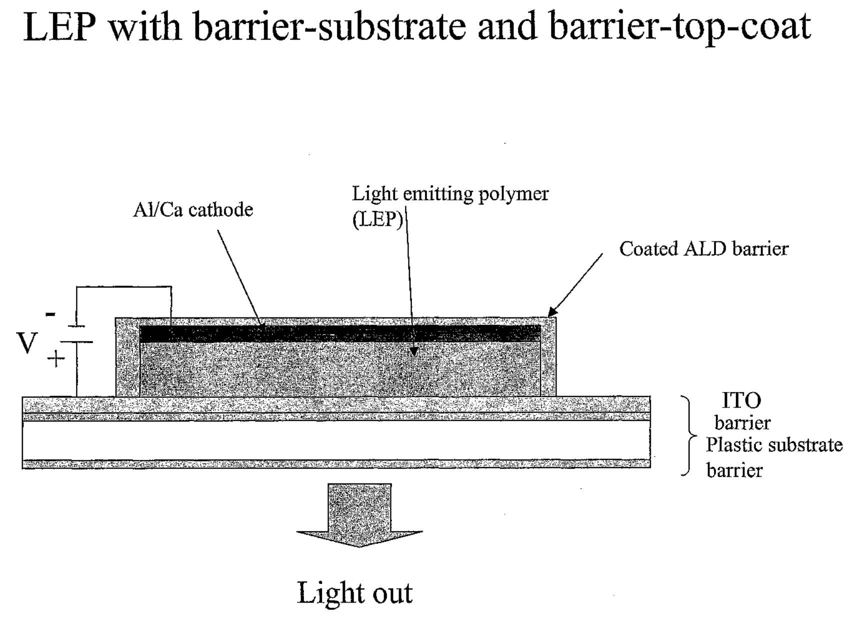
(54) Title: BARRIER FILMS FOR PLASTIC SUBSTRATES FABRICATED BY ATOMIC LAYER DEPOSITION


LEP with barrier-substrate and barrier-top-coat

(57) Abstract: Gas permeation barriers can be deposited on plastic or glass substrates by atomic layer deposition (ALD). The use of the ALD coatings can reduce permeation by many orders of magnitude at thicknesses of tens of nanometers with low concentrations of coating defects. These thin coatings preserve the flexibility and transparency of the plastic substrate. Such articles are useful in container, electrical and electronic applications.

WO 2004/105149 A1

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

TITLE

BARRIER FILMS FOR PLASTIC SUBSTRATES FABRICATED BY ATOMIC LAYER DEPOSITION

FIELD OF THE INVENTION

The present invention relates to an article comprising a plastic or glass substrate and an atmospheric gas penetration barrier fabricated by atomic layer deposition. The article may be a component of an electrical or electronic device such as an organic light emitting diode. The article may also be used as a container for applications where gas permeation is important.

TECHNICAL BACKGROUND

Featherby and Dehaven (WO 2001067504) disclose a hermetically coated device. Formation of such a device includes the steps of providing an integrated semiconductor circuit die, applying a first layer comprising an inorganic material which envelopes the circuit die, and applying a second layer enveloping the circuit die.

Aintila (WO 9715070 A2) discloses contact bump formation on metallic contact pad areas on the surface of a substrate comprising using atomic layer epitaxy to form an oxide layer on the substrate which is opened at required points in the subsequent process step.

Aftergut and Ackerman (US 5641984) disclose a hermetically packaged radiation imager including a moisture barrier. A dielectric material layer is deposited in an atomic layer expitaxy technique as part of the sealing structure.

Aftergut and Ackerman (US 5707880) disclose a hermetically packaged radiation imager including a moisture barrier comprising a dielectric material layer deposited by atomic layer expitaxy.

None of the references disclosed a permeation barrier comprising a polymer or glass substrate.

SUMMARY OF THE INVENTION

This invention describes an article comprising:

a) a substrate made of a material selected from the group consisting of plastic and glass, and
b) a film deposited upon said substrate by atomic layer deposition.

The present invention is further an article comprising:

a) A substrate made of a material selected from the group consisting of plastic and glass;
b) an adhesion layer coated; and
c) a gas permeation barrier deposited by atomic layer deposition.

Another embodiment of the present invention is an article comprising:

a) a substrate made of a material selected from the group consisting of plastic and glass;
b) an organic semiconductor, and
c) a gas permeation barrier deposited by atomic layer deposition.

A yet further embodiment of the present invention is an article comprising:

a) A substrate made of a material selected from the group consisting of plastic and glass,
b) A liquid crystal polymer, and
c) a gas permeation barrier deposited by atomic layer deposition

The invention further describes an embodiment that is an enclosed container.

Another embodiment of the present invention is an electrical or electronic device.

Yet another embodiment of the present invention is a light-emitting polymer device.

Yet another embodiment of the present invention is liquid crystalline polymer device.

The invention further describes an organic light emitting diode.

Another embodiment of the present invention is a transistor.

Yet another embodiment of the present invention is a circuit comprising a light emitting polymer device.

A still further article is an organic photovoltaic cell.

A second article taught herein comprises a plurality of layers, each layer comprising one article, as described above, wherein the articles are in contact with each other. In one embodiment of this second article of the articles above are in contact with each other by lamination means.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows a light-emitting polymer device with a barrier substrate and a barrier top coat.

Figure 2 shows a light-emitting polymer device with a barrier substrate and a barrier capping layer.

Figure 3 shows an organic transistor with a barrier substrate and a barrier capping layer.

Figure 4 shows an organic transistor with a barrier substrate and a barrier capping layer.

Figure 5 shows the measured optical transmission through 0.002 inch thick polyethylene naphthalate (PEN) coated with 25 nm of Al_2O_3 barrier film.

DETAILED DESCRIPTION

The permeation of O_2 and H_2O vapor through polymer films is facile. To reduce permeability for packaging applications, polymers are coated with a thin inorganic film. Al-coated polyester is common. Optically transparent barriers, predominantly SiOx or AlO_y, made either by physical vapor deposition (PVD) or chemical vapor deposition (CVD), are also used in packaging. The latter films are commercially available and are known in the industry as "glass-coated" barrier films. They provide an improvement for atmospheric gas permeation of about 10x, reducing transmission rates to about 1.0 cc O_2/m^2/day and 1.0 ml H_2O/m^2/day through polyester film (M. Izu, B. Dotter, and S. R. Ovshinsky, J. *Photopolymer Science and Technology*., vol. 8 1995 pp 195-204). While this modest improvement is a reasonable compromise between performance and cost for many high-volume packaging applications, this performance falls far short of packaging requirements in electronics. Electronic packaging usually requires at least an order of magnitude longer desired lifetime than, for example, beverage containing. As an example, flexible displays based on organic light emitting polymers (OLEDs), fabricated on flexible polyester substrates need an estimated barrier improvement of 10^5-10^6x for exclusion of atmospheric gases since gases can seriously degrade both the light-emitting polymer and the water-sensitive metal cathode which can frequently be Ca or Ba.

Because of their inherent free volume fraction, the intrinsic permeability of polymers is, in general, too high by a factor 10^4-10^6 to achieve the level of protection needed in electronic applications, such as flexible OLED displays. Only inorganic materials, with essentially zero permeability, can provide adequate barrier protection. Ideally, a defect-free, continuous thin-film coating of an inorganic should be impermeable to atmospheric gases. However, the practical reality is that thin films have defects, such as pinholes, either from the coating process or from substrate imperfections which compromise barrier properties. Even grain boundaries in films can present a pathway for facile permeation. For the best barrier properties, films should be deposited in a clean environment on clean, defect-free substrates. The film structure should be amorphous. The deposition process should be non-directional, (i.e. CVD is preferred over PVD) and the growth mechanism to achieve a featureless microstructure would ideally be layer-by-layer to avoid columnar growth with granular microstructure.

Atomic layer deposition (ALD) is a film growth method that satisfies many of these criteria for low permeation. A description of the atomic layer deposition process can be found in “Atomic Layer Epitaxy,” by Tuomo Suntola in Thin Solid Films, vol. 216 (1992) pp. 84-89. As its name implies, films grown by ALD form by a layer by layer process. In general, a vapor of film precursor is absorbed on a substrate in a vacuum chamber. The vapor is then pumped from the chamber, leaving a thin layer of absorbed precursor, usually essentially a monolayer, on the substrate. A reactant is then introduced into the chamber under thermal conditions, which promote reaction with the absorbed precursor to form a layer of the desired material. The reaction products are pumped from the chamber. Subsequent layers of material can be formed by again exposing the substrate to the precursor vapor and repeating the deposition process. ALD is in contrast to growth by common CVD and PVD methods where growth is initiated and proceeds at finite numbers of nucleation sites on the substrate surface. The latter technique can lead to a columnar microstructures with boundaries between columns along which gas permeation can be facile. ALD can produce very thin films with extremely low gas permeability, making such films attractive as barrier layers for packaging sensitive electronic devices and components built on plastic substrates.

This invention describes barrier layers formed by ALD on plastic substrates and useful for preventing the passage of atmospheric gases. The substrates of this invention include the general class of polymeric materials, such as described by but not limited to those in *Polymer Materials*, (Wiley, New York, 1989) by Christopher Hall or *Polymer Permea*bility, (Elsevier, London, 1985) by J. Comyn. Common examples include polyethylene terephthalate (PET) and polyethylene naphthalate (PEN), which are commercially available as film base by the roll. The materials formed by ALD, suitable for barriers, include oxides and nitrides of Groups IVB, VB, VIB, IIIA, and IVA of the Periodic Table and combinations thereof. Of particular interest in this group are SiO_2, Al_2O_3, and Si_3N_4. One advantage of the oxides in this group is optical transparency which is attractive for electronic displays and photovoltaic cells where visible light must either exit or enter the device. The nitrides of Si and Al are also transparent in the visible spectrum.

The precursors used in the ALD process to form these barrier materials can be selected from precursors known to those skilled in the art and tabulated in published references such as M. Leskela and M. Ritala, "ALD precursor chemistry: Evolution and future challenges," in *Journal de Physique IV*, vol. 9, pp 837-852 (1999) and references therein.

The preferred range of substrate temperature for synthesizing these barrier coatings by ALD is 50°C-250°C. Too high temperature (>250°C) is incompatible with processing of temperature-sensitive plastic substrates, either because of chemical degradation of the plastic substrate or disruption of the ALD coating because of large dimensional changes of the substrate.

The preferred thickness range for barrier films is 2 nm-100 nm. A more preferred range is 2-50 nm. Thinner layers will be more tolerant to flexing without causing the film to crack. This is extremely important for polymer substrates where flexibility is a desired property. Film cracking will compromise barrier properties. Thin barrier films also increase transparency in the cases of electronic devices where input or output of light is important. There may be a minimum thickness corresponding to continuous film coverage, for which all of the imperfections of the substrate are covered by the barrier film. For a nearly defect-free substrate, the threshold thickness for good barrier properties was estimated to be at least 2 nm, but may be as thick as 10 nm.

Some oxide and nitride barrier layers coated by ALD may require a "starting" or "adhesion layer" to promote adhesion to the plastic substrate or the article requiring protection. The preferred thickness of the adhesion layer is in the range of 1 nm -100 nm. The choice of the materials for the adhesion layer will be from the same group of barrier materials. Aluminum oxide and silicon oxide are preferred for the adhesion layer, which may also be deposited by ALD, although other methods such as chemical and physical vapor deposition or other deposition methods known in the art may also be suitable.

The basic building block of the barrier structure is either: (A) a single barrier layer with or without an adhesion layer, coated by ALD on a plastic or glass substrate, or (B) a barrier layer with or without an adhesion layer, coated by ALD on each side of a plastic substrate. This basic structure can then be combined in any number of combinations by laminating this building block to itself to form multiple, independent barrier layers. It is known in the art of barrier coatings that multiple layers, physically separate, can improve the overall barrier properties by much more than a simple multiplicative factor, corresponding the number of layers. This is demonstrated, for example, in *J. Phys. Chem. B* 1997, vol. 101, pp 2259-2266, "Activated rate theory treatment of oxygen and water transport through silicon oxide/poly(ethylene terephthalate) composite barrier structures," by Y. G. Tropsha and N. G. Harvey. This follows because the path for diffusing gas molecules is tortuous through multiple barrier layers that are separated. The effective diffusion path is much larger than the sum of the thickness of the individual layers.

Another barrier configuration involves directly coating the electronic or electro-optical device, requiring protection. In this regard, ALD is particularly attractive because it forms a highly conformal coating. Therefore devices with complex topographies can be fully coated and protected.

EXAMPLES

Example 1

Figure 1 shows a schematic representation of a light-emitting polymer device. For simplicity, the light emitting polymer device is shown as the light-emitting polymer (LEP) sandwiched between two electrodes. In practice, a hole-conducting and/or electron-conducting layer can be inserted between the appropriate electrode and the LEP layer to increase device efficiency. The anode is a layer of indium-tin oxide and the cathode is a Ca/Al layer composite. With a voltage applied between the electrodes, holes injected at the anode and electrons injected at the cathode combine to form excitons which decay radioactively, emitting light from the LEP. The LEP is typically a photosensitive polymer such as polyphenylene vinylene (PPV) or its derivatives. The cathode is frequently Ba or Ca and is extremely reactive with atmospheric gases, especially water vapor. Because of the use of these sensitive materials, the device packaging needs to exclude atmospheric gases in order to achieve reasonable device lifetimes. In Figure 1, the package is comprised of a barrier-substrate which can be plastic or glass on which the LEP device is deposited and then a top coated barrier film. The substrate is comprised of a polyester film, polyethylene naphthalate (PEN) which is 0.004 inch thick. Each side of the PEN film is coated with a 50 nm thick film of Al_2O_3, which is deposited by atomic layer deposition, using trimethylaluminum as the precursor for aluminum and ozone (O_3) as the oxidant. The substrate temperature during deposition is 150° C. In the ALD process, the PEN substrate is placed in a vacuum chamber equipped with a mechanical pump. The chamber is evacuated. The trimethylaluminum precursor is admitted to the chamber at a pressure of 500 millitorr for approximately 2 seconds. The chamber is then purged with argon for approximately 2 seconds. The oxidant, ozone, is then admitted to the chamber at approximately 500 millitorr for approximately 2 seconds. Finally, the oxidant is purged with argon for approximately 2 seconds. This deposition process is repeated approximately 50 times to obtain a coating approximately 100 nanometers in thickness. The Al_2O_3 layer is optically transparent in the visible. The coated substrate may be flexed without loss of the coating. One of the Al_2O_3 barriers is coated with indium-tin oxide transparent conductor by rf magnetron sputtering from a 10% (by weight) Sn-doped indium oxide target. The ITO film thickness is 150 nm. The LEP is spin coated on the ITO electrode, after which a cathode of 5 nm Ca with about 1 μm of Al are thermally evaporated from Ca and Al metal sources, respectively. This LEP device is then coated with a 50 nm-thick, top barrier layer film of Al_2O_3, deposited by atomic layer deposition, again using trimethylaluminum as the precursor for aluminum and ozone (O_3) as the oxidant. The resulting structure is now impervious to atmospheric gases.

<u>Example 2</u>

Another version of a packaging scheme is shown in Figure 2. The top-coated barrier is replaced by an identical substrate barrier structure

(Al_2O_3/PEN/Al_2O_3) without an ITO electrode as described in the Example 1 above. This capping barrier structure is sealed to the substrate barrier using a layer of epoxy.

Example 3

Figure 3 illustrates a protection strategy with ALD barrier coatings for an organic transistor. The transistor shown is a bottom gate structure with the organic semiconductor as the final or top layer. Because most organic semiconductors are air sensitive and prolonged exposure degrades their properties, protection strategies are necessary. In Figure 3 the package is comprised of a barrier-substrate on which the transistor is deposited and then sealed to an identical capping barrier structure. The substrate is comprised of a polyester film, polyethylene naphthalate (PEN), 0.004 inch thick. Each side of the PEN film is coated with a 50 nm thick film of Al_2O_3, which is deposited by atomic layer deposition, using trimethylaluminum as the precursor for aluminum and ozone (O_3) as the oxidant. The substrate temperature during deposition is 150°C. In the ALD process, the PEN substrate is placed in a vacuum chamber equipped with a mechanical pump. The chamber is evacuated. The trimethylaluminum precursor is admitted to the chamber at a pressure of 500 millitorr for approximately 2 seconds. The chamber is then purged with argon for approximately 2 seconds. The oxidant, ozone, is then admitted to the chamber at approximately 500 millitorr for approximately 2 seconds. Finally, the oxidant is purged with argon for approximately 2 seconds. This deposition process is repeated approximately 50 times to obtain a coating approximately 100 nanometers in thickness. A gate electrode of 100 nm thick Pd metal is ion-beam sputtered through a shadow mask on to the barrier film of Al_2O_3. A gate dielectric of 250 nm Si_3N_4 is then deposited by plasma-enhanced chemical vapor deposition, also through a mask to allow contact to the metal gate. This is followed by patterning of 100 nm-thick Pd source and drain electrodes, ion beam sputtered on the gate dielectric. Finally the top organic semiconductor, e.g. pentacene, is thermally evaporated through a shadow mask that allows contact to source-drain electrodes. The entire transistor is capped with an Al_2O_3/PEN/Al_2O_3 barrier-structure, sealed to substrate barrier with an epoxy sealant.

Example 4

In Figure 4, the capping barrier of Example 3 can be replaced by a single layer of 50 nm-thick Al_2O_3, deposited by atomic layer deposition, using trimethylaluminum as the precursor for aluminum and ozone (O_3) as the oxidant. Both packaging structures for the organic transistor device are impervious to atmospheric gases. The plastic substrate with barrier coatings can also be replaced by an impermeable glass substrate. The barrier capping layer is comprised of an initial adhesion layer of silicon nitride deposited by plasma-enhanced chemical vapor deposition at room temperature, followed by a 50 nm-thick Al2O3 barrier, deposited by atomic layer deposition, as described in Example 3.

Example 5

A substrate film of polyethylene terephthalate (PEN), 0.002 inches thick, was coated by atomic layer deposition at 120° C with Al_2O_3 about 25 nm thick on one side of the PEN substrate. Prior to evaluating its permeability properties the coated PEN substrate was flexed at least once to a radius of at least 1.5 inches to remove the coated Al_2O_3-coated PEN substrate from the rigid silicon carrier wafer, to which it was attached with Kapton® tape during ALD deposition. The oxygen transport rate with 50% relative humidity was measured with a commercial instrument (MOCON Ox-Tran 2/20) through the film with Al_2O_3 deposited by ALD. After 80 hours of measurement time, within the measurement sensitivity (.005 cc-O_2 /m^2/day), no oxygen transport (<0.005 cc/m^2/day) through the barrier film was detected, in spite of the severe prior flexing. For comparison, we measured oxygen transport of about 10 cc-O_2/m2/day through an uncoated PEN substrate. Figure 5 shows that the optical transmission for this Al_2O_3-coated PEN barrier and uncoated PEN is the same (>80% transmittance above 400 nm) verifying the transparency of the thin Al_2O_3 barrier coating.

CLAIMS

What is claimed is:

1. An article comprising:

a) a substrate made of a material selected from the group consisting of plastic and glass, and

b) a gas permeation barrier deposited on said substrate by atomic layer deposition.

2. An article comprising:

a) a substrate made of a material selected from the group consisting of plastic and glass,

b) an adhesion layer coated, and

c) a gas permeation barrier deposited an said substrate by atomic layer deposition.

3. An article comprising:

a) a substrate made of a material selected from the group consisting of plastic and glass,

b) an organic semiconductor, and

c) a gas permeation barrier deposited by atomic layer deposition.

4. An article comprising:

a) a substrate made of a material selected from the group consisting of plastic and glass,

b) a liquid crystal polymer, and

c) a gas permeation barrier deposited by atomic layer deposition

5. The article of any one of Claims 1, 2, 3 or 4 where the article is an enclosed container.

6. The article of any one of Claims 1, 2, 3 or 4 where the article is an electrical or electronic device.

7. The article of any one of Claims 1, 2, 3 or 4 where the article is a light-emitting polymer device.

8. The article of any one of Claims 1, 2, 3 or 4 where the article is an organic light emitting diode.

9. The article of any one of Claims 1, 2, 3 or 4 where the article is a transistor.

10. The article of any one of Claims 1, 2, 3 or 4 where the article is a circuit comprising a light emitting polymer device.

11. The article of any one of Claims 1, 2, 3 or 4 where the article is a circuit comprising a transistor.

12. The article of any one of Claims 1, 2, 3 or 4 wherein the article is an organic photovoltaic cell.

13. The article of any one of Claims 1, 2, 3 or 4 wherein the a gas permeation barrier deposited by atomic layer deposition is deposited on a top side and a bottom side of the polymer.

14. A second article comprising a plurality of layers, each layer comprising one article, as described in any one of Claims 1, 2, 3 or 4, wherein articles are in contact to each other.

15. The second article of claim 11 wherein the articles of any one of Claims 1, 2, 3 or 4 are in contact with each other by lamination means.

16. The article of any one of Claims 1, 2, 3 or 4 wherein the article is a liquid crystal display.

LEP with barrier-substrate and barrier-top-coat

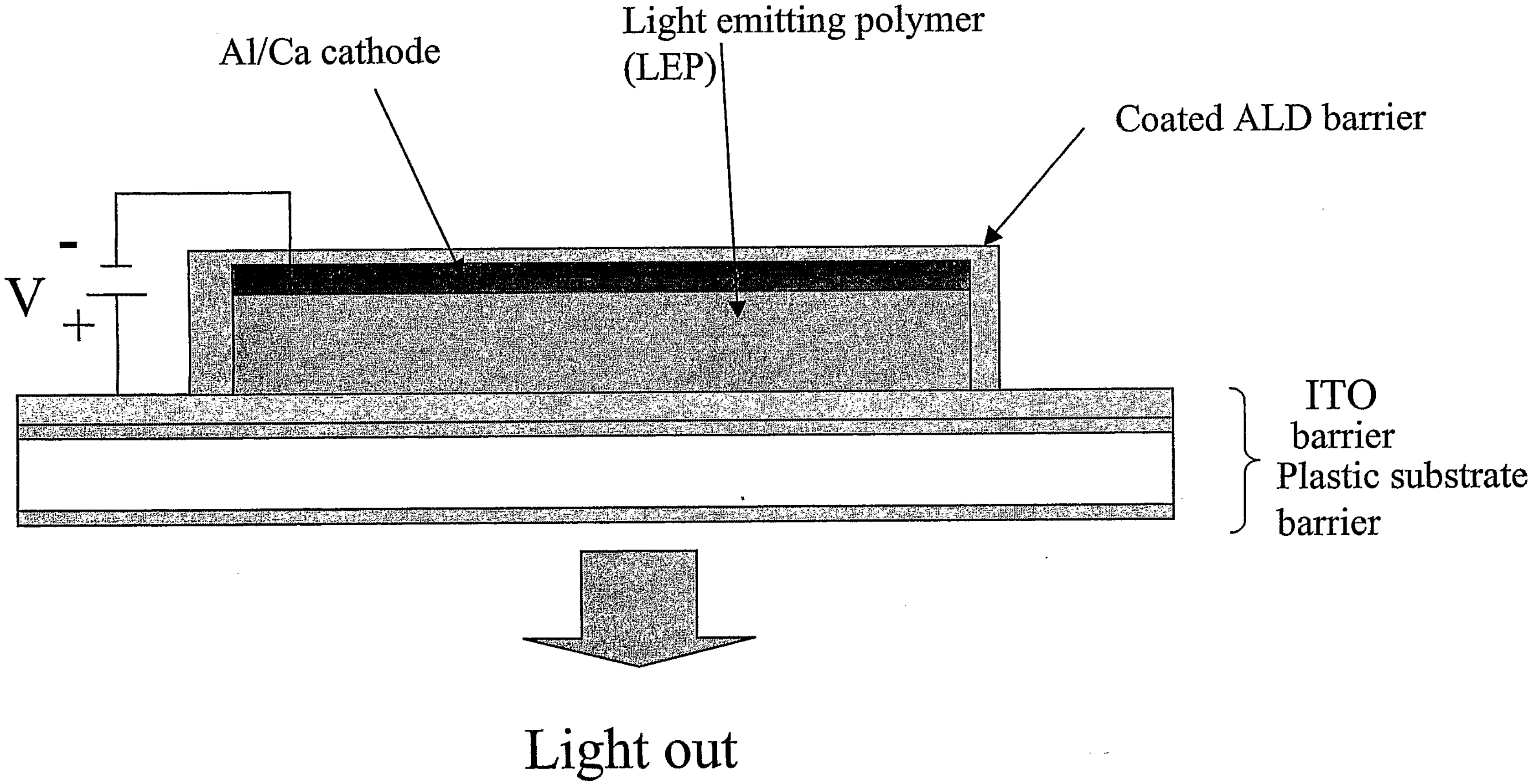


FIG. 1

LEP with barrier-substrate and barrier-capping layer

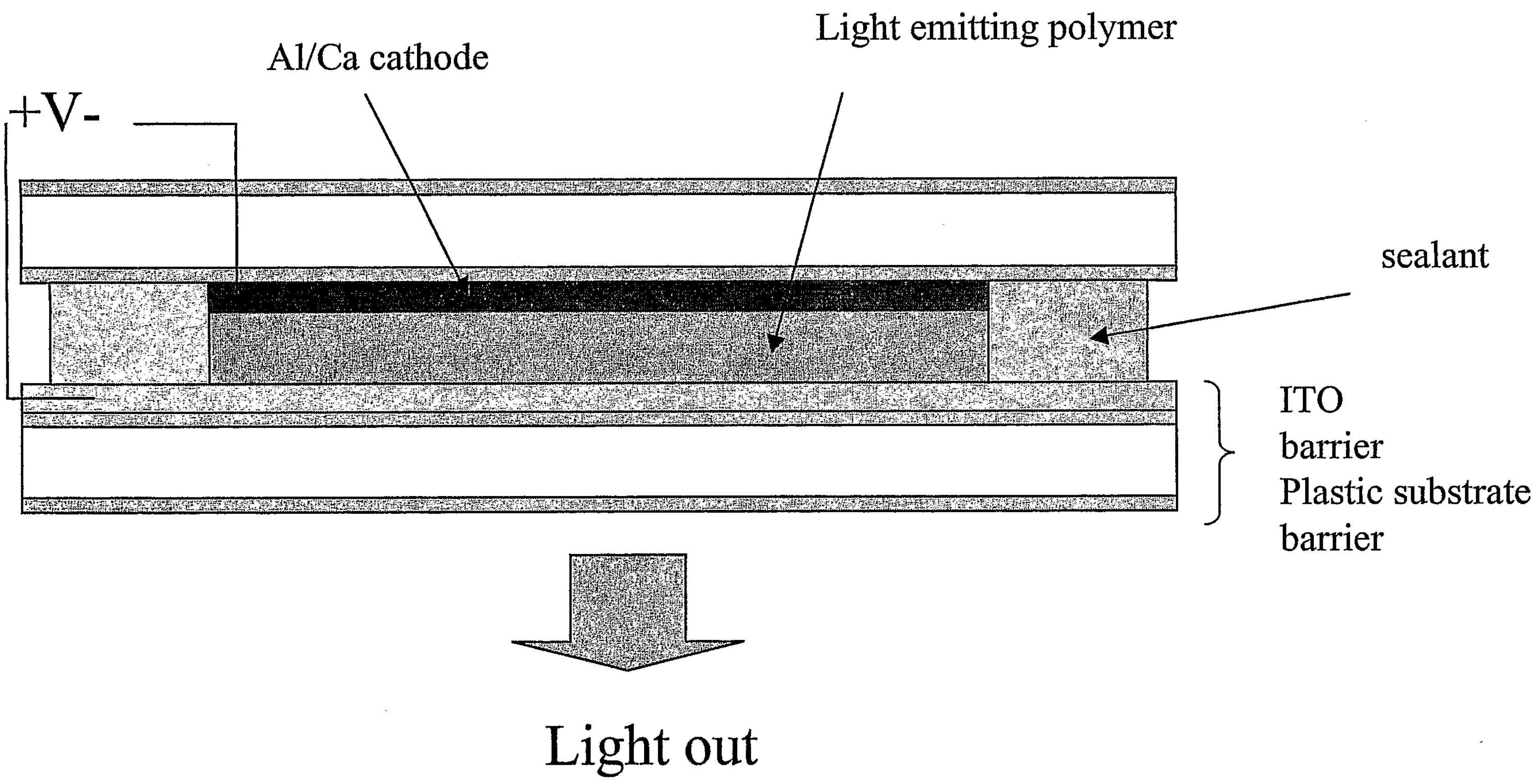


FIG. 2

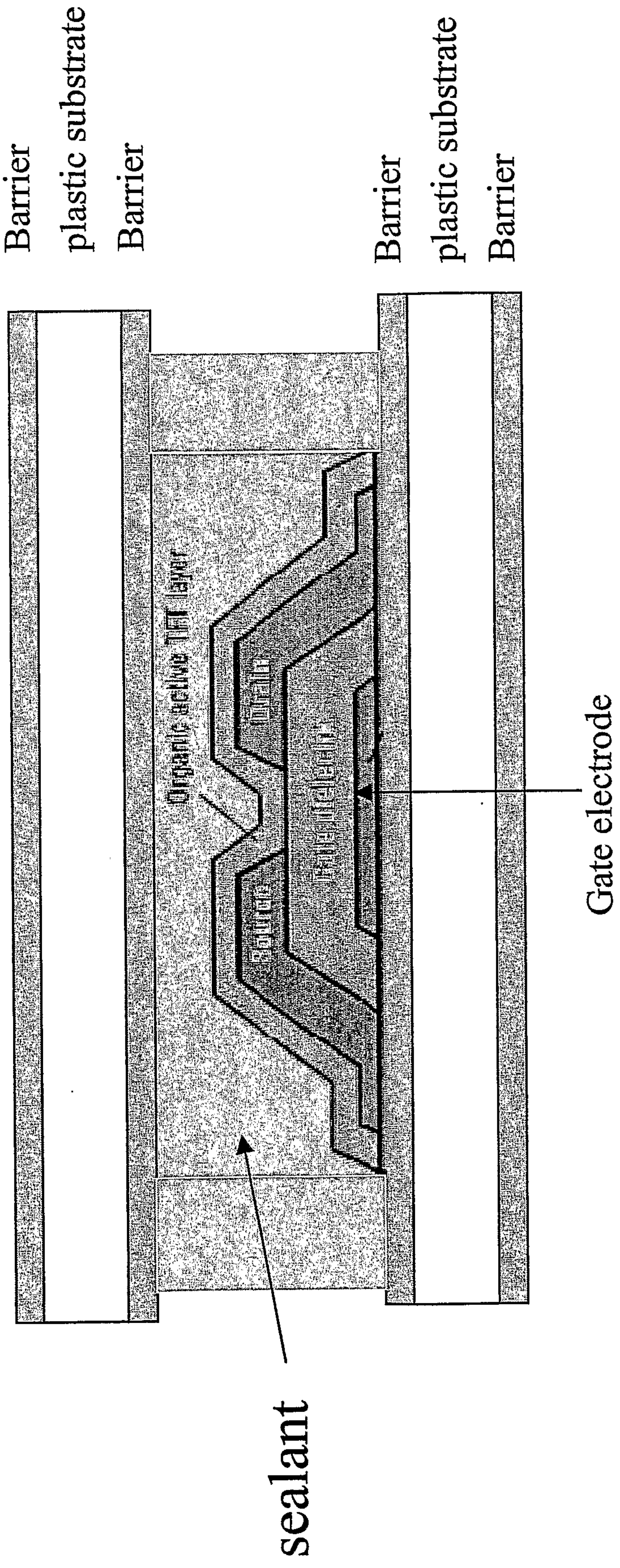

Barrier
plastic substrate
Barrier
Barrier
plastic substrate
Barrier
Organic active TFT layer
Drain
Source
Gate dielectric
Gate electrode
sealant

FIG. 3

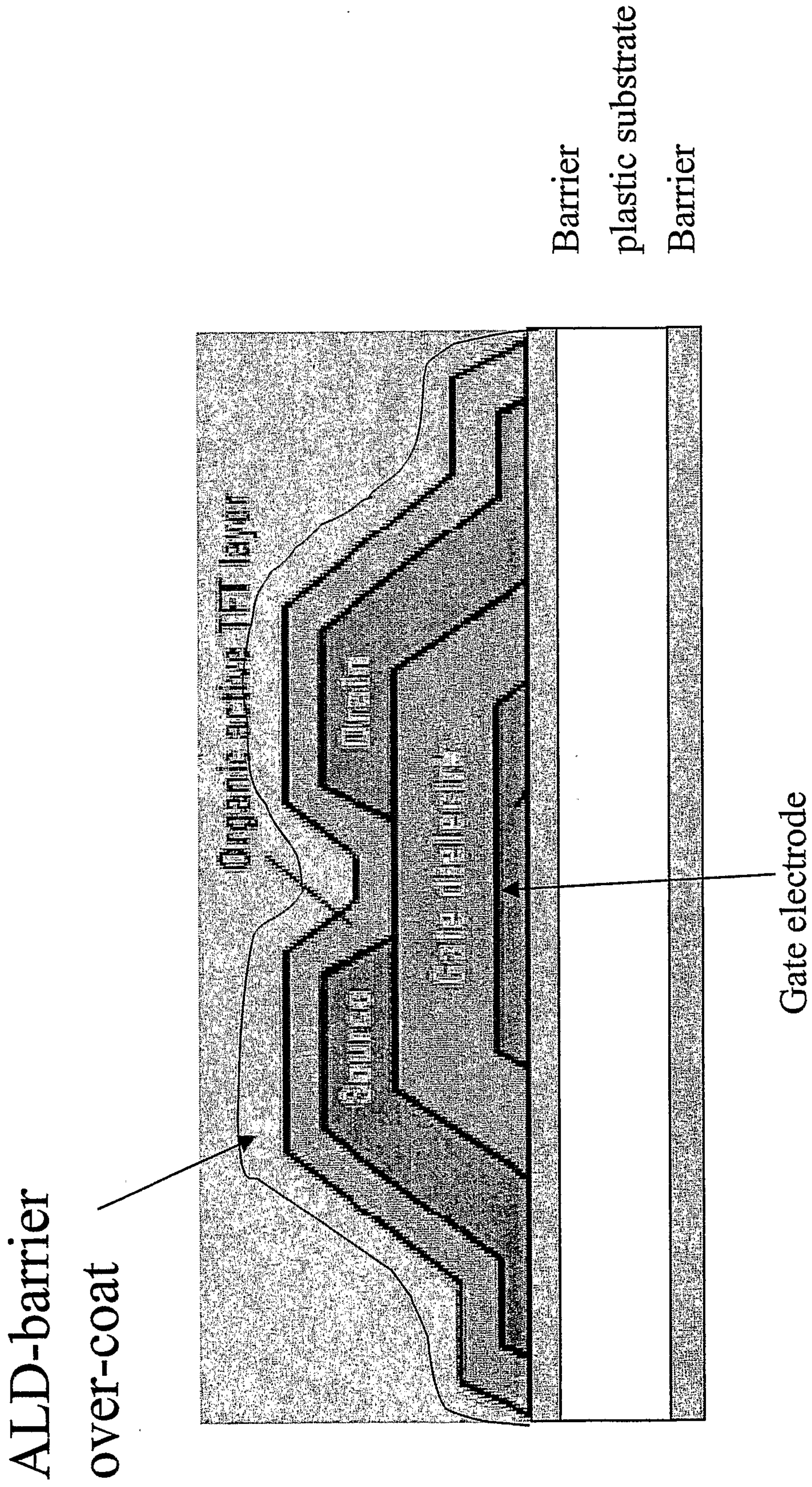

Barrier
plastic substrate
Barrier
Organic active TFT layer
Drain
Source
Gate dielectric
Gate electrode
ALD-barrier
over-coat

FIG. 4

Figure 5. Optical Transmission of Un-coated PEN and PEN with 25 nm thick ALD Al_2O_3 barrier film

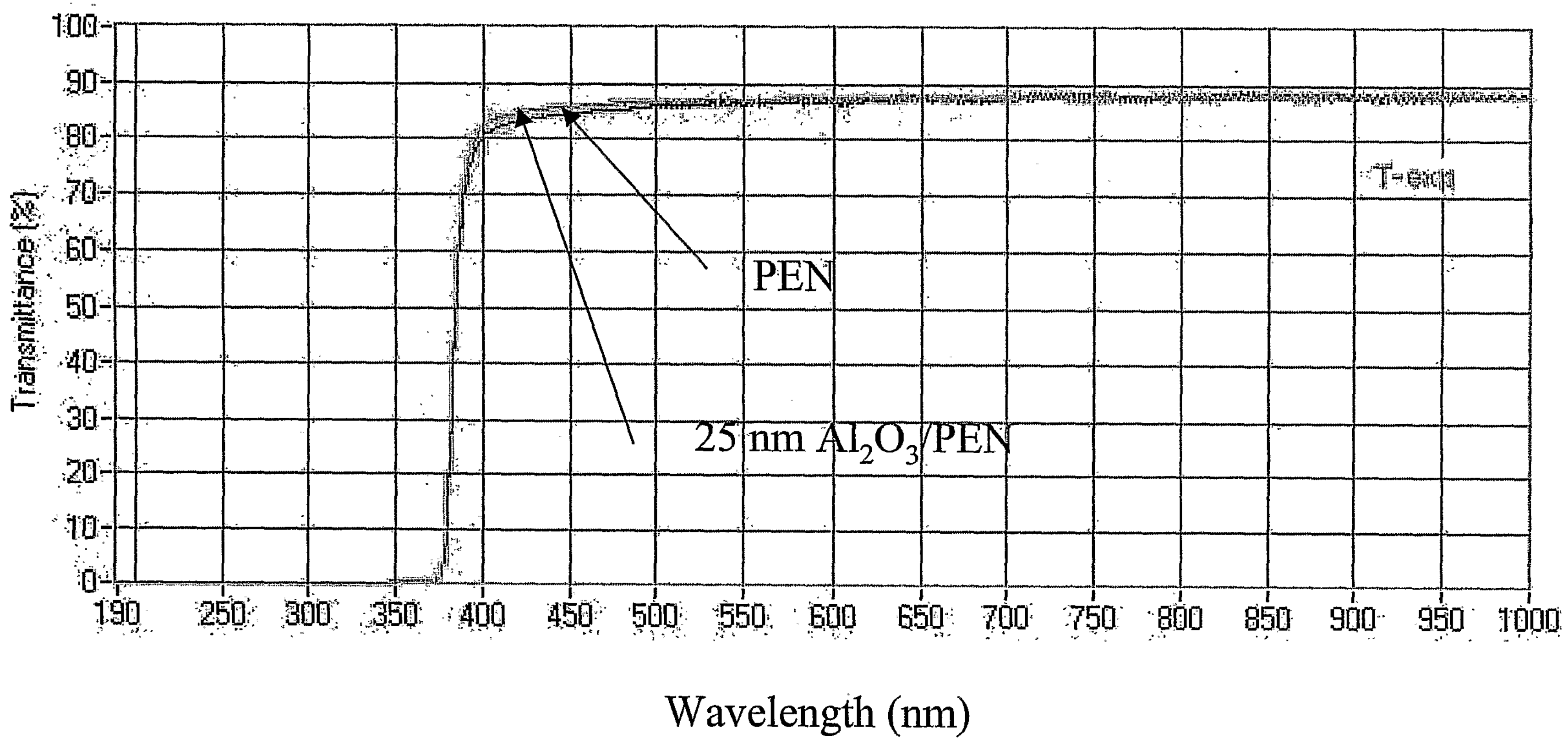


FIG. 5

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US2004/015270

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H01L51/10

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H01L G02F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 01/82390 A (EMAGIN CORP) 1 November 2001 (2001-11-01) page 1, lines 13-19 page 2, lines 9-21 page 3, lines 3-8,13-24 page 4, lines 2-7,11-14,20-23 page 5, lines 2-9,15-21 page 6, lines 1-4 page 8, lines 13-25 page 9, lines 1-3 page 10, lines 12-17 page 11, line 16 - page 12, line 7 page 13, line 16 - page 14, line 14 ----- -/--	1-16

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search 10 November 2004	Date of mailing of the international search report 19/11/2004
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Authorized officer Joffreau, P-O

1

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 02/071506 A (EMAGIN CORP) 12 September 2002 (2002-09-12) page 1, lines 15-20 page 2, lines 9-21 page 3, lines 3-8,17-23 page 4, lines 2-7,11-20 page 5, lines 1-20 page 8, lines 3-10,20-22 page 11, lines 9-25 page 12, lines 1-20 page 14, lines 9-18 page 14, line 21 - page 15, line 13 -----	1-16
Y	US 5 693 956 A (LEE HSING-CHUNG ET AL) 2 December 1997 (1997-12-02) column 2, lines 3-67 column 3, lines 1-23 -----	1-16
Y	US 5 757 126 A (HARVEY III THOMAS B ET AL) 26 May 1998 (1998-05-26) page 1, lines 24-38 column 2, lines 6-25,48-60 column 4, lines 26-55 column 5, lines 28-38 column 5, line 57 - column 6, line 14 -----	1-16
Y	WO 00/08899 A (UNIAX CORP) 17 February 2000 (2000-02-17) page 1, lines 8-12 page 4, lines 21-26 page 5, lines 16-22 page 5, line 25 - page 6, line 14 page 9, lines 1-13 page 12, line 7 - page 13, line 12 -----	1-16
A	WO 99/02277 A (FED CORP) 21 January 1999 (1999-01-21) page 1, lines 9,10,18-23 page 3, lines 2-4 page 4, line 24 - page 5, line 7 page 7, line 11 - page 8, line 25 -----	1-16
A	WO 01/89006 A (BATTELLE MEMORIAL INSTITUTE) 22 November 2001 (2001-11-22) page 1, lines 2,3,20,21 page 4, lines 1-16,25-29 page 6, lines 11-14 page 7, lines 3-9,13-15 page 9, lines 14-16,22-28 page 11, lines 19-3 -----	1-16

INTERNATIONAL SEARCH REPORT

ernational application No.
PCT/US2004/015270

Box II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☒ Claims Nos.: 1,2,14 (all partially)
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:
see FURTHER INFORMATION sheet PCT/ISA/210

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

Continuation of Box II.2

Claims Nos.: 1,2,14 (all partially)

Present claims 1, 2 and 14 relate to an extremely large number of possible products. Support within the meaning of Article 6 PCT and/or disclosure within the meaning of Article 5 PCT is to be found, however, for only a very small proportion of the products claimed. In the present case, the claims so lack support, and the application so lacks disclosure, that a meaningful search over the whole of the claimed scope is impossible. Consequently, the search has been carried out for those parts of the claims which appear to be supported and disclosed, namely those parts relating to the products encompassed an organic semiconductor such as an OLED or a liquid crystal polymer.

The applicant's attention is drawn to the fact that claims relating to inventions in respect of which no international search report has been established need not be the subject of an international preliminary examination (Rule 66.1(e) PCT). The applicant is advised that the EPO policy when acting as an International Preliminary Examining Authority is normally not to carry out a preliminary examination on matter which has not been searched. This is the case irrespective of whether or not the claims are amended following receipt of the search report or during any Chapter II procedure. If the application proceeds into the regional phase before the EPO, the applicant is reminded that a search may be carried out during examination before the EPO (see EPO Guideline C-VI, 8.5), should the problems which led to the Article 17(2) declaration be overcome.

INTERNATIONAL SEARCH REPORT

Information on patent family members

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PCT/US2004/015270

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