(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
6 August 2015 (06.08.2015)

WIPO | PCT

(10) International Publication Number
WO 2015/114205 A1

(51) International Patent Classification:
H01L 51/52 (2006.01) *B32B 18/00* (2006.01)
B82Y 30/00 (2011.01) *C23C 16/455* (2006.01)
B82Y 40/00 (2011.01)

(21) International Application Number:
PCT/FI2015/050032

(22) International Filing Date:
21 January 2015 (21.01.2015)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
1401506.9 29 January 2014 (29.01.2014) GB

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

(54) Title: A BARRIER COATING

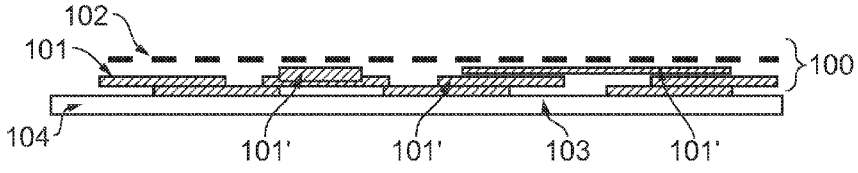

FIG. 1

(57) Abstract: The invention relates to a barrier coating (100) for a surface (103) of a substrate (104) comprising a plurality of two-dimensional platelets (101) of a first material; and at least another layer (102) covering the first layer.

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A barrier coating

TECHNOLOGICAL FIELD

Examples of the present disclosure relate to an apparatus and method for providing a barrier coating. In particular, though without prejudice to the foregoing, certain examples relate to a protective barrier coating for Organic Light Emitting Diode displays.

BACKGROUND

Electronic displays are vulnerable to damage due to the ingress of contaminants, such as moisture, from the ambient environment. For example, Organic Light Emitting Diode (OLED) displays are acutely vulnerable to damage by water and oxygen due to the polymeric substrates on to which OLED displays are typically fabricated. Polymeric substrates typically used have poor inherent barrier properties and poor surface qualities as compared to glass substrates. OLED displays, and their polymeric substrates, can also be flexible which presents additional difficulties. The provision of a single barrier layer may not provide an adequate level of barrier protection. However, where multiple barrier layers are provided to seek to provide adequate barrier protection to block moisture transport, the adding of multiple barrier layers to a display/device may increase its overall thickness and reduces its flexibility. Moreover, since typically multiple barrier layers are not dynamically flexible, after repeated bending they tend to form cracks which destroy the barrier integrity.

The listing or discussion of any prior-published document or any background in this specification should not necessarily be taken as an acknowledgement that the document or background is part of the state of the art or is common general knowledge. One or more examples of the present disclosure may or

may not address one or more of the background issues. Certain examples seek to provide a dynamically flexible barrier coating for protecting surfaces, such as flexible OLED displays.

BRIEF SUMMARY

According to at least some but not necessarily all examples of the disclosure there is provided an apparatus comprising: a layer comprising a plurality of two-dimensional platelets of a first material; and at least another layer covering the first layer; wherein the apparatus is configured to form a barrier coating for a surface.

According to at least some but not necessarily all examples of the disclosure there is provided a multilayer display protector comprising the apparatus as above.

According to at least some but not necessarily all examples of the disclosure there is provided a display comprising a display element and the apparatus as above.

According to at least some but not necessarily all examples of the disclosure there is provided a hand held electronic device comprising a user input device and the display as above.

According to at least some but not necessarily all examples of the disclosure there is provided a method of manufacturing the apparatus as above.

According to at least some but not necessarily all examples of the disclosure there is provided a method for providing a barrier coating to a surface, the method comprising causing, at least in part, actions that result in: providing

a layer, comprising a plurality of two-dimensional platelets of a first material, to the surface; and covering the first layer with at least another layer.

BRIEF DESCRIPTION OF THE DRAWINGS

For a better understanding of various examples that are useful for understanding the detailed description reference will now be made by way of example only to the accompanying drawings in which:

Figure 1 schematically illustrates an example of an apparatus according to the present disclosure;

Figure 2 schematically illustrates a further example of an apparatus according to the present disclosure;

Figure 3 schematically illustrates a yet further example of an apparatus according to the present disclosure;

Figure 4 schematically illustrates a yet further example of an apparatus according to the present disclosure;

Figures 5A and 5B schematically illustrate a plan view and side-on view of an example of a layer of an apparatus according to the present disclosure;

Figure 6 schematically illustrates an electronic device for use with examples of an apparatus according to the present disclosure;

Figure 7 schematically illustrates an example of a method according to the present disclosure;

Figures 8A and 8B illustrate a test performed on a conventional barrier coating;

Figures 9A and 9B illustrate a test performed on a barrier coating in accordance with an example of an apparatus according to the present disclosure; and

Figures 10A and 10B show transmission light microscopy images of an example of an apparatus according to the present disclosure.

DETAILED DESCRIPTION

The Figures schematically illustrate an apparatus 100 which comprises: a first layer 101 and a second layer 102 which covers the first layer. The layers may be disposed on a surface 103 of a substrate 104 so as to provide a barrier coating for the surface. In various examples, the apparatus provides a protective barrier coating which seeks to prevent the ingress/passages of contaminants (not least such as: moisture, particles and oils) through the surface/substrate.

The first layer comprises a plurality of two-dimensional platelets 101' of a first material. The term 'two-dimensional platelets of a first material' is a generic term that encompasses, for example, materials having a platelet morphology i.e. having a thickness of only a few nanometres (e.g. less than 1, 5 or 10 nm) but a lateral extent of several micrometres (e.g. 0.1 – 10 μm or 0.1 - 100 μm), two-dimensional sheet material, for example flakes of Graphene Oxide, or nanoplatelets. Other materials having two-dimensional platelets that might be used in examples of the present disclosure include: Boron Nitride, Graphene, functionalised Graphene, Fluorographene, Transition metal Dichalcogenides, Molybdenum Disulphide, Single layer Silicon - Silicene, Mica, Bentonite clay materials or any inorganic material with a platelet morphology.

For certain two-dimensional materials the platelets can be 'atomically thin' monolayers, i.e. made of only a one atom thick layer. For example, the thickness of monolayer Graphene may be around 0.34 nm and about 0.8 nm for Graphene Oxide.

The layer of two-dimensional platelets provides multiple terraces of atomically flat platelets which creates a planarised surface thereby providing a seed layer, or base coating layer, having an upper surface

devoid of, or having reduced, surface defects such as pin-holes. Advantageously, this allows for preferential deposition of a subsequent layer.

Furthermore, the two-dimensional platelets of the layer can slide over each other (i.e. provide 'lubricant' behaviour) which has the advantage of improved tolerance to flexing/bending and enhanced resilience to crack formation in the layer itself due to deformation of the layer, e.g. during bending. Moreover, such a layer also improves the tolerance of the subsequent layer, which is disposed on the platelet layer, to withstand bending.

Thus, various examples of the present disclosure may provide a barrier coating with improved barrier protection/passivation and enhanced ability to withstand flexing/bending.

In certain examples, the subsequent layer may be a conformal coating layer deposited via Atomic Layer Deposition (ALD) so as to provide a high quality pin-hole free ALD coating. In certain other examples, the subsequent layer may be another layer of two-dimensional platelets but of a different material to the first platelet material. For example, one layer may comprise a hydrophilic platelet material whereas the other layer may comprise a hydrophobic platelet material. Such alternating layers may provide barrier protection against contaminants such as moisture, organic substances/molecules and other substances/particles.

In some further particular examples, one of the layers may be modified so as to draw away contaminants from one region of the layer to another region of the layer. Advantageously, certain examples not only inhibit the ingress of moisture through the layers but also actively guide any moisture which does permeate through to outer edges of the apparatus.

An example of an apparatus/multi-layer barrier coating will now be described with reference to the Figures. Similar reference numerals are used in the Figures to designate similar features. For clarity, all reference numerals are not necessarily displayed in all figures.

Figure 1 schematically illustrates an example of an apparatus 100. Figure 1 focuses on the functional components necessary for describing the operation of the apparatus. The apparatus comprises a multi-layer barrier coating 100 having a first layer 101 disposed on a surface 103 of a substrate 104. The first layer 101 comprises a plurality of two-dimensional platelets 101' of a first material. The first material may comprises, for example, one of: Graphene Oxide, Boron Nitride, Graphene, functionalised Graphene, Fluorographene, Transition metal Dichalcogenides, Molybdenum Disulphide, Silicene, Mica, Bentonite or an inorganic material with a platelet morphology. Such materials can be stacked in controlled architectures to provide a layer which is transparent and has moisture resistance.

The two-dimensional platelets 101' form a thin film that substantially covers the surface 104 of the substrate which is to be protected. The plurality of two-dimensional platelets 101' may be applied in a tessellated fashion to the surface or the plurality of two-dimensional platelets 101' may be applied in such a manner so as to overlay/overlap one another, forming sub layers of platelets 101' within layer 101, to ensure substantially complete coverage of the entire surface 104 which is to be protected by the platelets with no exposed areas not covered by at least two-dimensional platelet.

The first layer 100 may comprise a single or a few sub layers (e.g. 1-5) of platelets 101'. Alternatively, the first layer may comprise many sub layers (e.g. 5-500) of platelets 101'. The first layer creates a planarised surface consisting of multiple terraces of atomically flat platelets 101' that cover the surface 104. Advantageously, this planarised surface of the first layer allows

for preferential deposition of a second layer 102, e.g. a conformal coating layer as in Figure 2 or a further layer of two-dimensional platelets as in Figure 3.

Figure 2 schematically illustrates an example of a multi-layered coating barrier 200 for protecting a surface 103 of a substrate 104. The multi layered coating barrier 200 comprises a first layer 101 of two-dimensional platelets 101' of a first material and a second layer 202. The second layer is a coating layer, e.g. a conformal coating layer of a thin film deposited on top of the planarised surface of the first layer via Atomic Layer Deposition (ALD). In certain examples, the second layer comprises an Aluminium based ALD coating, such as Aluminium Oxide or Alumina. It is to be appreciated that the conformal coating second layer could comprise other metallic compounds (e.g. metallic: oxides, nitrides and sulphides) which may be deposited via ALD.

ALD coatings, or other conformal coating layers, can provide an extremely low permeability water/oxygen barrier. However typically, particularly for polymeric substrates, surface defects in the substrate disrupt the deposition of high quality, pin-hole free, conformal ALD coatings (or other conformal coating layer). The provision of an initial layer of two-dimensional platelets of a first material creates a planarised surface which, advantageously, allows for preferential deposition of a subsequent layer. For example a high quality pin-hole free conforming coating/ALD coating may be deposited onto the planarised surface of the first layer of platelet material.

The ALD coating/film layer may also help the two-dimensional platelets to bind to the substrate thereby improving integrity of the hybrid multilayer coating.

Figure 3 schematically illustrates an example of a multi layered coating barrier 300 for protecting a surface 103 of a substrate 104. The multi layered coating barrier 300 comprises a first layer 101 comprising a plurality of two-dimensional platelets 101' of a first material and a second layer 302 comprising a plurality of two-dimensional platelets 302' of a second material which is different to the first material thereby providing a hybrid multilayer coating. The second material may comprise, for example, one of: Graphene Oxide, Boron Nitride, Graphene, functionalised Graphene, Fluorographene, Molybdenum Disulphide, or an inorganic material with a platelet morphology.

One of the first and second materials may be selected so as to provide a water super-permeable layer/film by using hydrophilic platelets, for example flakes of Graphene Oxide (GO). GO solutions may be applied via spray coating, spin coating, slot die coating, blade or rod coating, air-knife coating, drop cast or printing techniques to form a layer/film which is water super-permeable but impermeable to any other molecules.

The other of the first and second material may be selected so as to provide a water impermeable layer/film by using hydrophobic platelets, for examples flakes of boron nitride (BN), Graphene or Fluorographene. Solutions of such material may be applied via slot-die coating, air-knife coating, rod coating, spray coating, spin coating, drop cast or printing techniques to form a layer/film which is impermeable to water but permeable to organic molecules.

The two types of layers/films can be combined in a multilayer structure, where the hydrophobic layer/film repels water and the hydrophilic layer/film repels oils and organic solvents.

Electrical conductivity of a layer could be provided by using Graphene solutions, which would also provide a water impermeable film.

Figure 4 illustrates an example of a multi layered coating barrier 400 in which different layers/films 101, 102, 403 may be stacked on top of each other, via subsequent printing or coating techniques. The multi layered coating barrier 400 comprises:

a first layer 101 of two-dimensional platelets 101' of a first material,

a second layer 302, overlaying the first layer, of two-dimensional platelets 302' of a second material, and

a third layer 403, overlaying the second layer, of two-dimensional platelets 403' of a third material.

Additional layers (not shown) may also be provided, such as a conformal coating deposited by ALD, or other vacuum deposition method such as: sputtering, evaporation, plasma-deposition, Chemical Vapour Deposition (CVD).

The first material may be different from the second material and the second material may be different from the third material.

One or more of the first, second and third materials may be selected to provide a water impermeable/hydrophobic layer and another one or more of the first, second and third materials may be selected to provide a water permeable/hydrophilic layer. In the example of Figure 4, a water permeable layer 302 of GO platelets 302' is sandwiched between two water impermeable layers 403 and 101 of BN platelets 403' and 101'. The upper BN layer 403 acts as a hydrophobic barrier against moisture, while any water which manages to permeate through this layer is confined to the middle GO layer 302 via the lower BN layer 101.

In certain examples of the apparatus, one of the layers may be configured/structured so as to draw away contaminants (e.g. water molecules, gas particles or organic molecules) or to draw contaminants from one region of the layer to another region of the layer.

Where such a layer is formed of a hydrophilic material, such as flakes of GO, the layer/film can act as a capillary medium to extract water from the coating. The hydrophilic layer/film may be structured in order to direct the flow of water molecules towards a periphery of the layer or an outside of the apparatus (and inhibit a flow of water molecules towards a central region of the layer or an inside of the apparatus). This way, a protective barrier layer can be provided with a built-in capability to eliminate water traces.

A hydrophilic GO layer, which is super-permeable to water molecules, may be configured/structured in such a way so as to guide/draw out water to the edges of the layer by creating low resistance permeation pathways / highly permeable pathways through which water molecules can diffuse to the edge of the layer.

In one example, a layer may be configured to comprise hydrophobic parts defining passages/channels of a hydrophilic material, such that the hydrophilic material acts as a capillary medium. For instance, a hydrophilic layer of GO flakes may be provided with areas of reduced Graphene Oxide (rGO), which is hydrophobic. The rGO may be obtained in the GO layer via local reduction of parts of the GO layer. The GO layer may be patterned by direct laser writing or by flash light irradiation so as to exploit a photonic reduction phenomenon whereby GO is reduced upon irradiation and turned into rGO. Such patterning may be applied to a single, continuous GO layer so as to create hydrophilic GO micro-channels/capillaries defined between portions/boundaries of hydrophobic reduced GO. The geometry of the patterning on the rGO and GO to define the channels/capillaries may

be a geometry suitable to favour the flow of water towards the outside edges of the layer. For example, fractal geometries may be provided, with increasing branching from the central/middle area of the layer to one or more peripheral regions or edges of the layer.

In another example, the layer may be configured/structured such that the separation distance between platelets in the layer is selectively varied. The vertical separation distance between platelets in the layer may affect the permeability to specific molecules. Accordingly, the vertical separation distance may be selectively controlled/tuned to control the permeability to specific molecules. For example, an average vertical separation distance between adjacent platelets located in a central region 502, as shown in Figures 5A and 5B, of the layer may be configured to be different from an average vertical separation distance between adjacent platelets in a peripheral region 503 of the layer.

The separation of platelets within a layer, such as a GO layer, may be selected/tuned via surface functionalization in such a way that the size of capillary pathways shrink from the centre to the sides of the GO layer.

Stacking separation of the platelets may be controlled by the use of functional groups attached to the platelets which prevent close-packing. The chain length of the functional groups can be selected/tuned to control the platelet separation, with longer chain groups leading to larger spacing. In this manner a platelet structure having controlled capillary channels between platelets can be created, e.g. so as to create a hybrid structure that has larger platelet separation in the centre of the layer, with progressively smaller separation towards the edges in order to guide moisture to the edges of the layer (where the moisture can be subsequently dealt with/disposed, e.g. via absorption or adsorption via getter particles).

Figures 5A and 5B schematically illustrate a plan view and side-on view respectively of a layer 501 of two-dimensional platelets for use in a multi-layered barrier coating of the present invention. Two functionalised GO areas are printed: a central region 502 of the layer may comprise pristine GO, whereas an outer/peripheral region 503 may comprise partially reduced GO, which is known to show a smaller distance between platelets. Such a structure may be obtained also by light reduction, e.g. printing the entire area with GO, masking the central region 502 and irradiating the peripheral region 503, e.g. by laser, flash light, so as to at least partially reduce the GO in the peripheral region to partially reduced GO. In this layer 501, the platelet separation decreases towards the edges of the layer 503 as compared with the larger platelet separation in the centre of the layer 502.

Partially reduced GO is a material where a reduction process (mainly consisting in the elimination of oxygen-containing functional groups) has been carried out only partially (i.e. some oxygen-containing functional groups are still present, but at a lesser extent with respect to pristine GO). The properties of partially reduced GO – such as hydrophilicity – are directly affected by the functional groups, and are therefore modified accordingly, for example partially reduced GO would be less hydrophilic that pristine GO, but more than reduced GO.

Figure 6 schematically illustrates an electronic device 600 comprising a display 601. Multi-layered barrier coatings comprising a layer of two-dimensional platelets as described above may be applied to the display 601 to allow creation of a dynamically flexible and foldable display device.

Certain examples of the present disclosure seek to provide a dynamically flexible barrier coating that can protect an OLED from water vapour ingress of more than $1x10^{-6}$ g/m^2/day. Such moisture resistance is highly desirable

for the fabrication of fully flexible, full colour, video rate capable displays that have to withstand dynamic flexibility.

The device 600 also comprises a user input 602 via which a user can interact and control the device. The user input 602 is shown here as buttons, but it is to be appreciated that any means for user input may be used, e.g. a touch sensitive screen or voice input.

The electronic device 600 may be a hand-portable electronic device, and may include, not least: mobile telephones, wireless communications devices, cameras, Personal Digital Assistants (PDAs) and tablet PCs. The portable electronic device may provide one or more audio/text/video communication functions (e.g. tele-communication, video-communication, and/or text transmission, Short Message Service (SMS)/ Multimedia Message Service (MMS)/emailing functions, interactive/non-interactive viewing functions (e.g. web-browsing, navigation, TV/program viewing functions), music recording/playing functions (e.g. MP3 or other format and/or (FM/AM) radio broadcast recording/playing), downloading/sending of data functions, image capture function (e.g. using a (e.g. in-built) digital camera), and gaming functions.

In certain particular examples, the two-dimensional platelet layer may be of a conductive material, such as Graphene flakes. Alternatively, the material of the layer may be doped so as to enhance its conductivity, for example by introducing conductive Graphene materials to the layer.

The barrier coating could be configured to be multi-functional by additionally being used as an electrode of an OLED device, e.g. an electrically conductive layer of the barrier coating could be used as an anode of an OLED device. Advantageously, not only does the barrier layer provide a protective barrier, but it also reduces the number of layers required

in the display device structure, since a separate anode is not required. Moreover, where Graphene flakes are used, improved charge injection may be provided that increases the luminosity/light output and efficiency of the OLED display device.

The barrier coating may be applied, not least for example, to: a surface 104 of a flexible substrate 105, for example an OLED display panel, to provide a protective barrier coating. The flexible substrate 105 may be a polymeric substrates, such as poly(ethyleneterephthalate) (PET) or polyethylene 2,6-naphthalate (PEN). Polyilmide, (PI), Polyaramid (PA), Polyether ether ketone (PEEK)

Whilst examples are discussed with respect to providing barrier coatings for such items, it will be appreciated that the barrier coating is not restricted to such use and could be applied to any surface, electronic component or environmentally/moisture sensitive object to improve passivation and barrier protection. For example the barrier coating could be applied to packaging for perishable goods, Photo Voltaic (PV) cells and Optical Photo Voltaic (OPV) cells.

Figure 7 schematically illustrates a flow chart of an example of a method 700 according to the present disclosure. In block 701, a first layer, comprising a plurality of two-dimensional platelets of a first material, is provided to the surface. The two-dimensional platelets may be applied via: slot-die coating, air-knife coating, rod coating, spray coating, spin coating, drop cast or printing techniques

Optionally, in block 702, the layer may be modified, for example so as to enable the layer to guide contaminants from one region of the layer to another region of the layer. In block 702A, the layer may be modified by selectively adjusting the separation distance of platelets in the layer, e.g.

such that the vertical separation distance is greater in a central area of the layer than a peripheral region of the layer. Control of the platelet separation distance may be achieved via surface functionalization to introduce functional groups to the layer of the first material. The chain lengths of the functional groups can be selected to control platelet separation, whereby longer chain groups give rise to longer platelet separation distances. In block 702B, the layer may be modified by selectively irradiating the layer, e.g. so as to pattern the layer with channels/passageways/capillaries in an arrangement so as to guide contaminants (e.g. water molecules or organic molecules) from a central region to a peripheral region of the layer.

In block 703 a second layer is provided on top of the first layer. The second layer may be another layer of two-dimensional platelets but of a second material different to the first material (e.g. such that one material is hydrophilic and the other is hydrophobic). The second layer may alternatively be a conformal coating, e.g. an ALD coating layer.

One or more further layers may additionally be provided, e.g. a further two-dimensional platelet layer or conformal coating layer.

The flowchart of Figure 7 represents one possible scenario among others. The order of the blocks shown is not absolutely required and one or more blocks may be performed in a different order or overlapping in time, in series or in parallel. One or more blocks may be omitted (e.g. blocks 702, 702A and 702B) or added or changed in some combination of ways.

For example, in another scenario, different functional groups may be already provided in solutions prior to film deposition. 2 dimensional platelets with different functionalization may be printed on different areas so as to provide hydrophobic/hydrophilic patterns. In this scenario, the modification block

702 would occur before the layer deposition block 701, i.e. the 2 dimensional platelet material for a layer is modified prior to it being deposited as a layer.

It will also be understood that each block, and combinations of blocks, can be implemented by special purpose hardware-based systems which perform the specified functions or steps. Accordingly, the blocks support: combinations of means for performing the specified functions; combinations of steps for performing the specified functions; and computer program instructions/algorithm for performing the specified functions.

In the above description, various stacked layers have been described. It should be appreciated that any number of intervening layers could also exist (including no intervening layers).

Figures 8A and 8B illustrate a 'Calcium Mirror' test performed on a conventional barrier coating. Whereas Figures 9A - 9B illustrate a 'Calcium Mirror' test performed on a barrier coating in accordance with an example of an apparatus according to the present disclosure.

The Calcium Mirror test quantifies the barrier properties of different materials on a polymeric substrate, in this case a polyethylene 2,6-naphthalate (PEN) substrate.

The barrier coating to be tested is deposited onto a PEN substrate. Next a thin layer of Calcium metal is evaporated on top of the barrier coating, this substrate is then adhered/laminated to an impermeable glass substrate so that the only point of ingress for water and oxygen is through the PEN + barrier. This process is done in an inert atmosphere glove box. Subsequently the samples are brought into ambient conditions to assess the barrier properties by tracking the optical transparency of the Calcium mirror.

Immediately after deposition the calcium forms a highly reflective silver mirror. Even small amounts of moisture or oxygen cause conversion of the Calcium metal to transparent Calcium Hydroxide, causing transparent spots to appear where moisture or oxygen has penetrated the barrier.

Figure 8A shows a sample of a PEN substrate with a standard coating of 5nm ALD Alumina layer barrier at the start of the test shortly after fabrication. The central section of Calcium is clearly visible. Figure 8B shows the PEN with 5nm of ALD test sample of Figure 8A after 24 hours in ambient conditions. The sample with only the Alumina barrier is fully transparent after 24 hours, indicating all the Calcium metal has been consumed by oxygen or moisture ingress.

Figure 9A shows another sample at the start of the test. This sample additionally comprises a layer of GO platelets, i.e. the PEN substrate is coated in GO platelets onto which a 5nm ALD Alumina layer barrier is provided. Initially after fabrication the central section of Calcium is clearly visible. Figure 9B shows the PEN with GO platelets and 5nm of ALD Alumina test sample of Figure 9A after 24 hours in ambient conditions. This sample, with the GO platelets underneath the Alumina layer, has only small regions of degradation, the majority of the Calcium metal remaining unreacted and protected from moisture and oxygen.

Figure 10A shows a transmission light microscopy image, at 200x magnification, of the test sample of Figure 9A, i.e. at the beginning of the test. Figure 10B shows a transmission light microscopy image, at 200x magnification, of the test sample of Figure 9B, i.e. after 24 hours. These optical micrograph images show that the improved barrier properties are localized to the GO platelets, since it can be seen that the Calcium metal has reacted and is transparent in the exposed regions between the platelets.

Features described in the preceding description may be used in combinations other than the combinations explicitly described.

Although features have been described with reference to certain examples, those features may also be present in other examples whether described or not. It should be appreciated that modifications to the examples given can be made without departing from the scope of the invention as claimed.

The term 'comprise' is used in this document with an inclusive not an exclusive meaning. That is any reference to X comprising Y indicates that X may comprise only one X or may comprise more than one X.

In this brief description, reference has been made to various examples. The description of features or functions in relation to an example indicates that those features or functions are present in that example. The use of the term 'example' or 'for example' or 'may' in the text denotes, whether explicitly stated or not, that such features or functions are present in at least the described example, whether described as an example or not, and that they can be, but are not necessarily, present in some of or all other examples. Thus 'example', 'for example' or 'may' refers to a particular instance in a class of examples. A property of the instance can be a property of only that instance or a property of the class or a property of a sub-class of the class that includes some but not all of the instances in the class.

Whilst endeavouring in the foregoing specification to draw attention to those features of the invention believed to be of particular importance it should be understood that the Applicant claims protection in respect of any patentable feature or combination of features hereinbefore referred to and/or shown in the drawings whether or not particular emphasis has been placed thereon.

CLAIMS

1. An apparatus comprising:
a layer comprising a plurality of two-dimensional platelets of a first material; and
at least another layer covering the first layer;
wherein the apparatus is configured to form a barrier coating for a surface.

2. The apparatus of claim 1, wherein the first material comprises one of: Graphene Oxide, Boron Nitride, Graphene, functionalised Graphene, Fluorographene, Transition Metal Dichalcogenides, Molybdenum disulphide, Silicene, Mica, Bentonite Clays or an inorganic material with a platelet morphology.

3. The apparatus of any one or more of previous claims 1 - 2, wherein the at least another layer comprises a conformal coating layer.

4. The apparatus of any one or more of previous claims 1 - 2, wherein the at least another layer comprises a plurality of two-dimensional platelets of a second material different to the first material.

5. The apparatus of claim 4, wherein the second material comprises one of:
Graphene Oxide, Boron Nitride, Graphene, functionalised Graphene, Fluorographene, Transition metal Dichalcogenides, Molybdenum Disulphide, Silicene, Mica, Bentonite clays or an inorganic material with a platelet morphology.

6. The apparatus of any one or more of the previous claims, comprising at least a yet further layer.

7. The apparatus of any one or more of the previous claims, wherein at least one of the layers is configured to be substantially hydrophilic.

8. The apparatus of any one or more of the previous claims, wherein at least one of the layers is configured to be substantially hydrophobic.

9. The apparatus of any one or more of the previous claims, wherein at least one of the layers is configured such that it is able to draw away contaminants from one region of the layer to another region of the layer.

10. The apparatus of any one or more of the previous claims, wherein at least one of the layers is configured to comprise hydrophobic parts defining passages of a hydrophilic material.

11. The apparatus of claim 10, wherein the passages are configured to draw out moisture from at least one peripheral region of the layer.

12. The apparatus of any one or more of the previous claims, wherein at least one of the layers is configured such that a separation distance between the two-dimensional platelets is selectively varied.

13. The apparatus of any one or more of the previous claims, wherein one of the layers is configured for use as an electrode.

14. The apparatus of any one or more of the previous claims, wherein the layers are substantially transparent.

15. The apparatus of any one or more of the previous claims, further comprising a substrate.

16. The apparatus of claim 15, wherein the substrate is flexible.

17. A multilayer display protector comprising an apparatus as claimed in any one or more of the previous claims.

18. A display comprising a display element and an apparatus as claimed in any one or more of the previous claims.

19. A hand held electronic device comprising a user input device and a display as claimed in claim 18.

20. An apparatus, as claimed in claim 1, wherein the barrier coating is configured to be an electrode of an OLED device.

21. A method for providing a barrier coating to a surface, the method comprising causing, at least in part, actions that result in:

providing a layer, comprising a plurality of two-dimensional platelets of a first material, to the surface; and

covering the first layer with at least another layer.

22. The method of claim 21, further comprising modifying the layer.

23. The method of claim 22, wherein modifying the layer comprises selectively adjusting platelet separation distance.

24. The method of any one of previous claims 22 - 23, wherein modifying the layer comprises selectively irradiating parts of the layer.

25. The method of any one of previous claims 22 - 24, wherein the layer is modified so as to enable the layer to guide contaminants from one region of the layer to another region of the layer.

26. An apparatus and method for providing a barrier coating substantially as hereinbefore described with reference to and/or as shown in the accompanying drawings.

27. Any novel subject matter or combination including novel subject matter disclosed, whether or not within the scope of or relating to the same invention as the preceding claims.

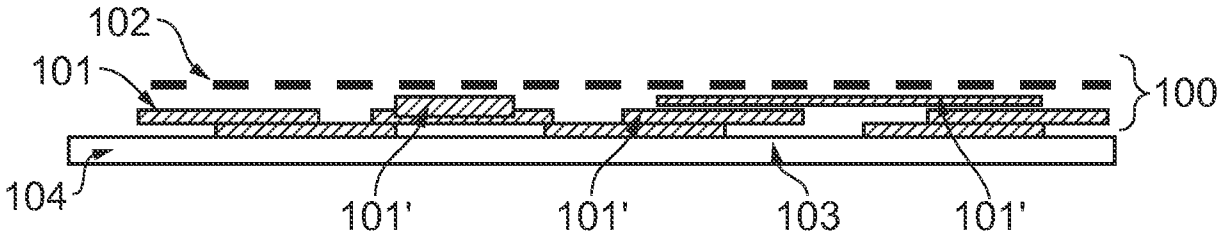

FIG. 1

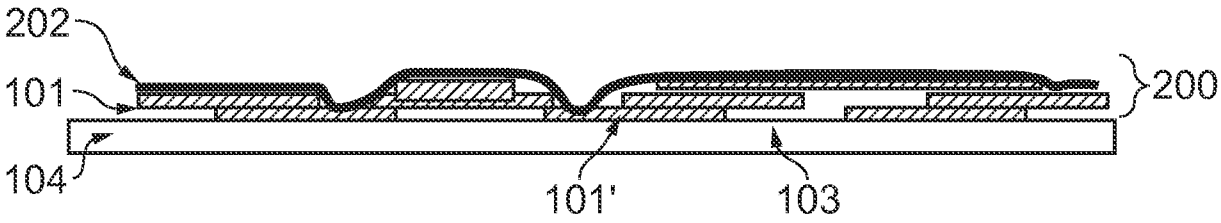

FIG. 2

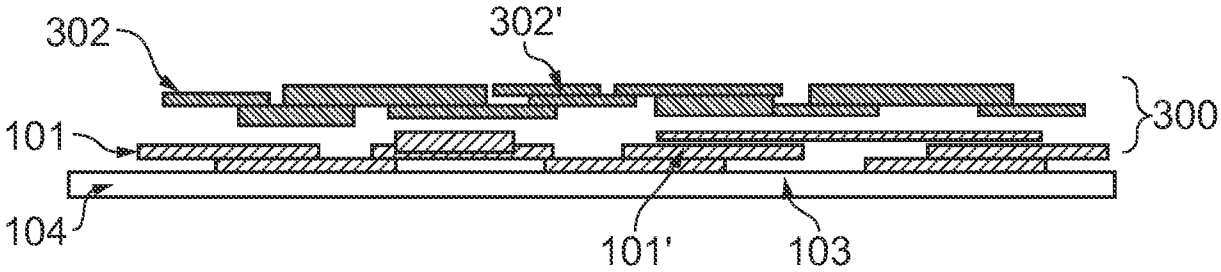

FIG. 3

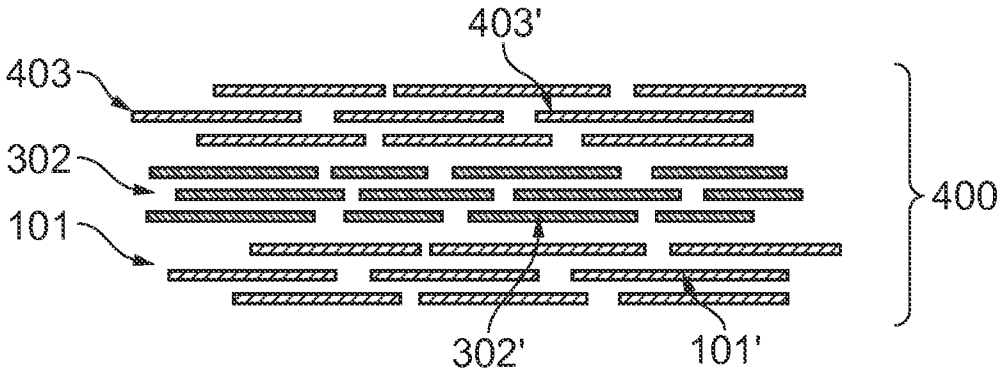

FIG. 4

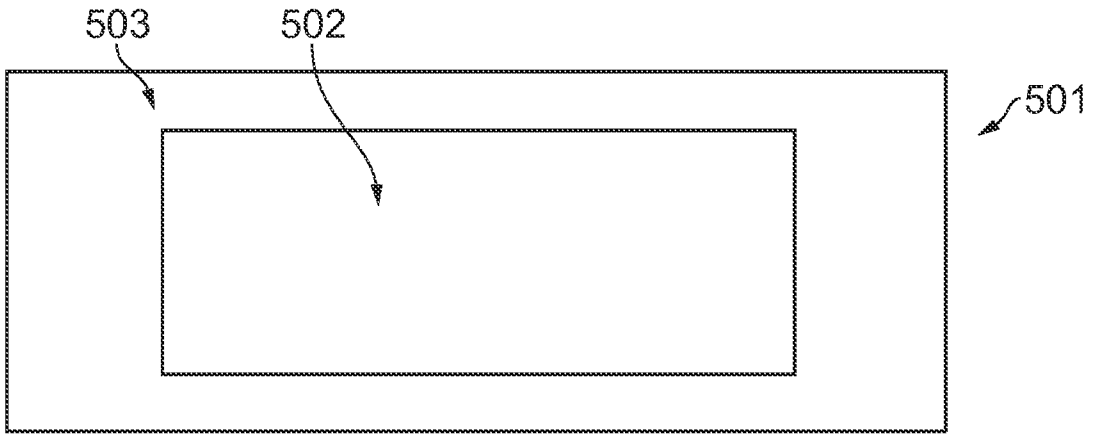

FIG. 5A

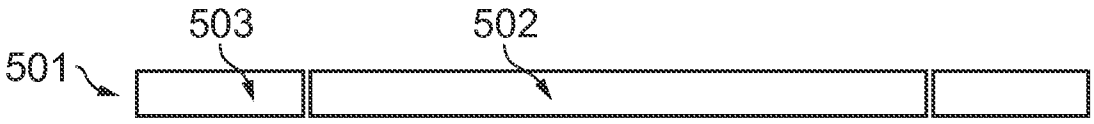

FIG. 5B

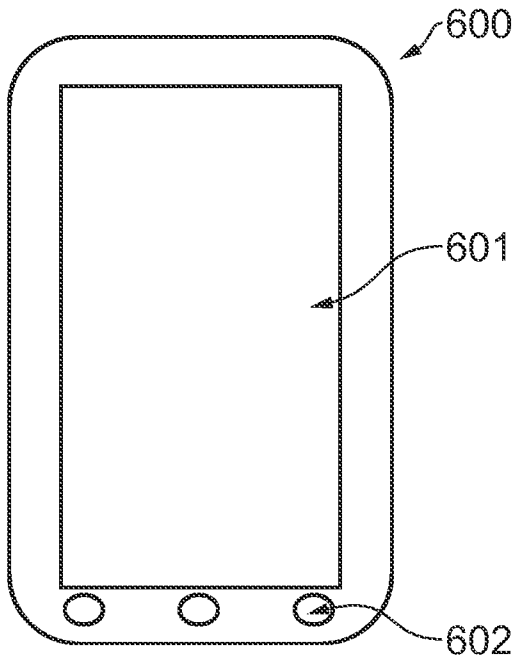

FIG. 6

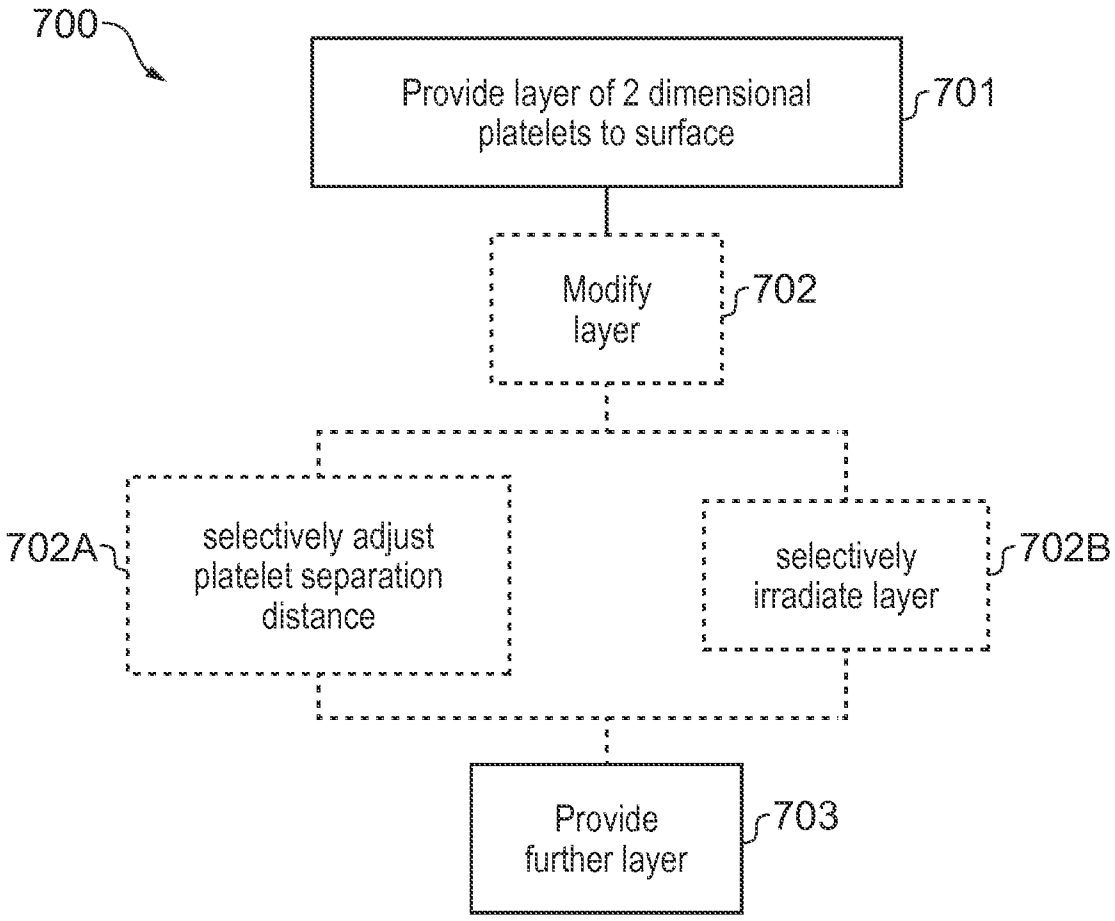
700
Provide layer of 2 dimensional platelets to surface
701
Modify layer
702
702A
selectively adjust platelet separation distance
selectively irradiate layer
702B
Provide further layer
703

FIG. 7

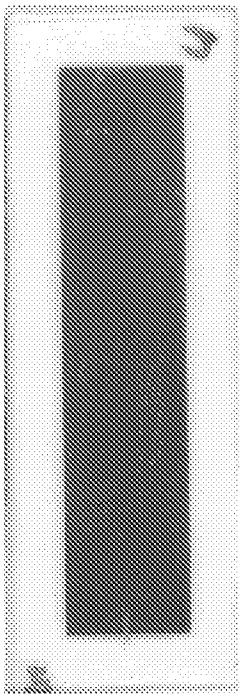

FIG. 8A

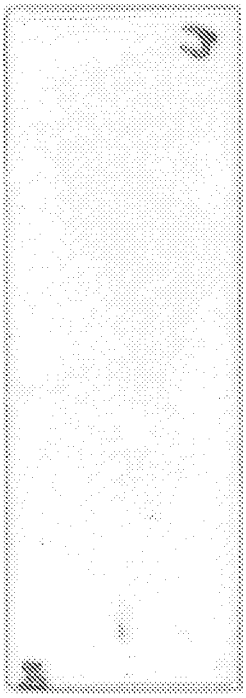

FIG. 8B

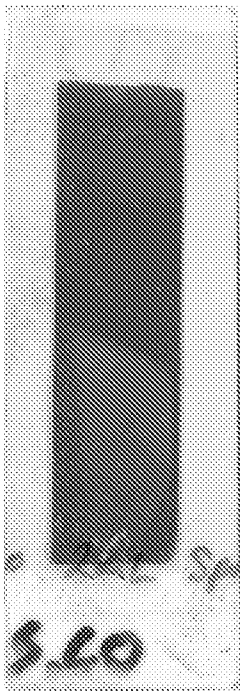

FIG. 9A

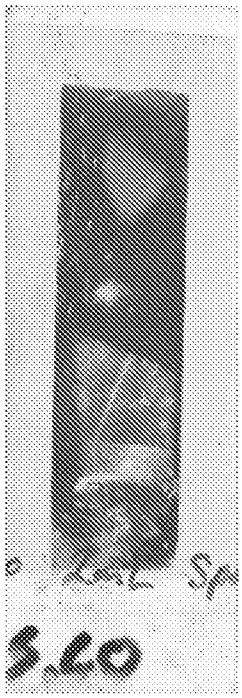

FIG. 9B

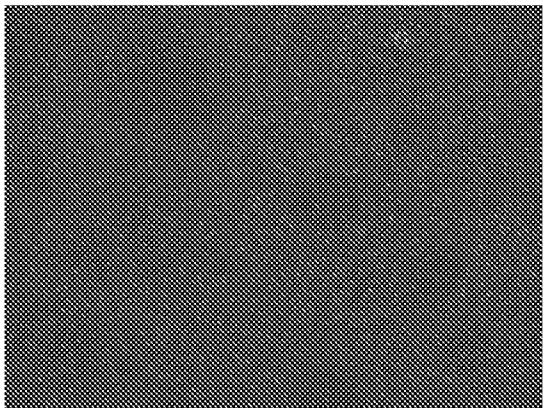

FIG. 10A

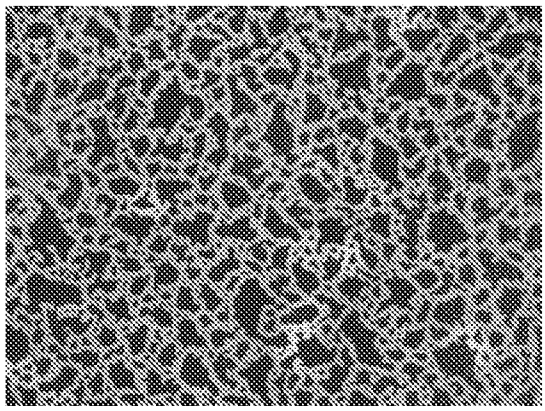

FIG. 10B

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI2015/050032

A. **CLASSIFICATION OF SUBJECT MATTER**

See extra sheet

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)

H01L, B82Y, C01B, B32B, C23C

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

FI, SE, NO, DK

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

EPO-Internal, WPIAP, XPESP

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 2445028 A1 (TNO [NL]) 25 April 2012 (25.04.2012)	1-3, 6-8, 10, 11, 14-19, 21, 22
A	abstract; paragraphs [0012]-[0014], [0016], [0041], [0042], [0088]; fig. 1	4, 5, 12, 13, 20, 23, 24
X	US 2005249901 A1 (YIALIZIS ANGELO [US] et al.) 10 November 2005 (10.11.2005) paragraphs [0002], [0011], [0016], [0036]-[0038]; figs. 2, 3	1-3, 6, 7, 14-19, 21, 22
X	US 2007284557 A1 (GRUNER GEORGE [US] et al.) 13 December 2007 (13.12.2007) paragraphs [0002], [0003], [0006]; claims 1-8	1-3, 6, 14-19, 21, 22
X	Ratanatawanate, C. et al., Layer-by-layer assembly of titanate nanosheets/poly- (ethylenimine) on PEN films, Mater. Lett. 2012, Vol. 66, pages 242-245. introduction; fig. 4	1-3, 14-19, 21, 22

☐ Further documents are listed in the continuation of Box C. ☒ See patent family 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 application or patent 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	Date of mailing of the international search report
04 May 2015 (04.05.2015)	05 May 2015 (05.05.2015)

Name and mailing address of the ISA/FI
Finnish Patent and Registration Office
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Authorized officer
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI2015/050032

Box No. 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.: 9, 25-27
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 extra sheet.

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 No. 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 additional fees, this Authority did not invite payment of additional fees.
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 and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT
Information on Patent Family Members

International application No.
PCT/FI2015/050032

Patent document cited in search report	Publication date	Patent family members(s)	Publication date
EP 2445028 A1	25/04/2012	CN 103299447 A	11/09/2013
		EP 2633567 A2	04/09/2013
		JP 2013544012 A	09/12/2013
		KR 20140007340 A	17/01/2014
		TW 201232861 A	01/08/2012
		US 2014049825 A1	20/02/2014
		WO 2012057615 A2	03/05/2012
US 2005249901 A1	10/11/2005	US 7781034 B2	24/08/2010
		EP 1753662 A2	21/02/2007
		JP 2007536169 A	13/12/2007
		WO 2005108215 A2	17/11/2005
US 2007284557 A1	13/12/2007	US 7449133 B2	11/11/2008
		US 2009017211 A1	15/01/2009
		US 7785557 B2	31/08/2010

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI2015/050032

CLASSIFICATION OF SUBJECT MATTER

IPC
H01L 51/52 (2006.01)
B82Y 30/00 (2011.01)
B82Y 40/00 (2011.01)
B32B 18/00 (2006.01)
C23C 16/455 (2006.01)

Extra Sheet

Claims 9 and 25 lack clarity and fail to meet the requirements of PCT Article 6 in so far as the subject matter for which protection is sought is not clearly defined. The functional information given in claim 9 “at least one of the layers is configured such that it is able to draw away contaminants from one region of the layer to another region of the layer”, and in claim 25 “the layer is modified so as to enable the layer to guide contaminants from one region of the layer to another region of the layer” does not enable a person skilled in the art to determine what technical features are necessary for carrying out said functions. In addition, the description of the present application does not give a clear disclosure of the subject matter of claims 9 and 25. Therefore, no novelty search can be carried out on claims 9 and 25.

The claims must not, in respect of the technical features of the invention, rely on references to the drawings (PCT Rule 6.2 (a)). As claim 26 only comprises technical features defined in a way that relies on references to the drawings, claim 26 was found unsearchable.

Independent claim 27 is unclear to such an extent that a meaningful search is impossible (PCT Article 6). Claim 27 is also not supported by the description as required by PCT Article 6, as its scope is broader than what is justified by the description. In addition, claim 27 comprises an alternative, which lacks unity with any of claims 1-26 (PCT Rule 13.1).

The applicant's attention is drawn to the fact that claims or a part of 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 (PCT Rule 66.1(e)). The applicant is advised that the policy of International Preliminary Examining Authorities is 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 the receipt of the international search report or during any Chapter II procedure.