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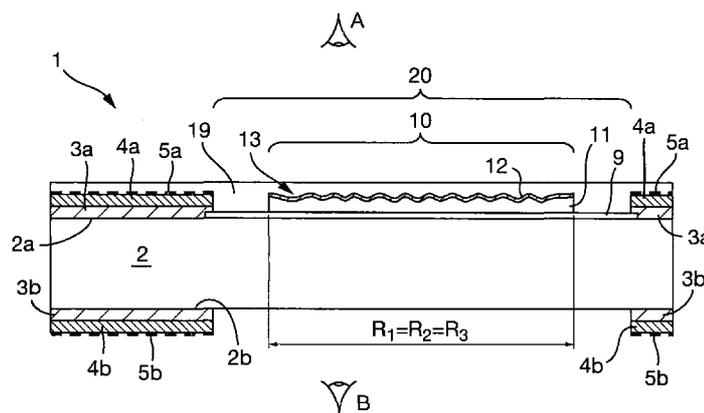
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(54) **Title:** SECURITY DOCUMENTS AND METHODS OF MANUFACTURE THEREOF

Fig. 1



(57) **Abstract:** A method of manufacturing a security document is disclosed, comprising:(a) providing a polymeric substrate having first and second surfaces;then performing the following steps (b), (c) and (d) in any order:(b) applying a curable material to a first region of the substrate on its first surface;(c) forming the curable material such that its surface distal from the substrate follows the contours of an optically variable effect generating relief structure and curing the curable material such that the relief structure is retained by the cured material; (d) applying one or more coating layers to the first and/or second surface(s) of the substrate to define a viewing region, the coating layer(s) being absent at least on the first surface across all or part of the first region;then:(e) applying a masking substance to the first surface of the substrate, excluding at least a second region which includes at least part of the first region, the overlapping portions of the first and second regions defining a third region; (f) depositing a reflection enhancing material onto the first surface of the substrate such that, in the third region, the reflection enhancing material is deposited onto the cured material and follows the contours of the relief structure;wherein the masking substance impedes the retention of the reflection enhancing material such that the reflection enhancing material is retained only in areas to which the masking substance was not applied.

SECURITY DOCUMENTS AND METHODS OF MANUFACTURE THEREOF

The present invention relates to security documents such as banknotes,
5 currency, identification documents, passports, cheques, visas, certificates and
the like, and methods for their manufacture. In particular, the invention relates to
security documents incorporating security devices in the form of optically
variable effect generating relief structures such as holograms and/or diffraction
10 gratings. The disclosed methods are particularly well adapted for integral
formation of such security devices on a security document having a polymeric
substrate, such as a polymer banknote.

Optically variable effect generating relief structures such as holograms and
diffraction gratings have been used widely over the last few years to impart
15 security to documents of value such as banknotes, credit cards, passports and
the like. Conventionally, the structure is provided on a transfer foil and then hot
stamped from the transfer foil onto the final document substrate. An early
example of this approach is described in US-A-4728377. Such techniques work
well with traditional security documents having substrates formed of paper, for
20 example. However, it can prove difficult to adhere such articles to other types of
substrate, such as polymer substrates. For instance, polymer-based banknotes
typically comprise a substrate of polypropylene, which can withstand
temperatures up to around 80 degrees C. Hot stamping methods commonly
operate at higher temperatures, e.g. around 250 to 300 degrees C, which would
25 cause damage to such substrates. Meanwhile, the use of cold adhesives has
generally proved unsuccessful since the bond between polymer and security
device is often not sufficiently robust.

In order to avoid such problems, alternative methods have been employed
30 including the use of "cast-cure" resins. A curable material is applied to the
polymer substrate and embossed with a desired relief structure. Simultaneously
or subsequently, the material is cured, e.g. by exposure to UV radiation, in order
to fix the relief structure. A metallic ink is then applied to the relief to provide a
reflective layer, in order to render the optically variable effect visible. An
35 example of such a method is disclosed in WO-A-2008/031 170.

Whilst this technique results in strong adhesion between the substrate and security device, due to bonding between the polymeric substrate and curable resin, the quality of the resulting security device is typically not optimal. One reason for this is the use of a metallic ink to enhance the optically variable replay, which does not give rise to as bright and clear an optical effect as is achievable in traditional transfer foil type devices which use a metal or high refractive index layer as the reflective material. This is because the reflective particles making up a metallic ink cannot conform to the relief structure to the same degree that can be achieved where a metal or HRI layer is applied to the relief. However, the use of metal or HRI layers is problematic since the methods required for deposition of such materials typically involve heating the substrate, which leads to warping. This gives rise to loss of registration between the curable resin region and the metallised area and/or between the curable resin region and coating layers or printed graphics on the document.

In accordance with the present invention, a method of manufacturing a security document comprises:

- (a) providing a polymeric substrate having first and second surfaces;
- then performing the following steps (b), (c) and (d) in any order:
- (b) applying a curable material to a first region of the substrate on its first surface;
 - (c) forming the curable material such that its surface distal from the substrate follows the contours of an optically variable effect generating relief structure and curing the curable material such that the relief structure is retained by the cured material;
 - (d) applying one or more coating layers to the first and/or second surface(s) of the substrate to define a viewing region, the coating layer(s) being absent at least on the first surface across all or part of the first region;
- then:
- (e) applying a masking substance to the first surface of the substrate, excluding at least a second region which includes at least part of the first region, the overlapping portions of the first and second regions defining a third region;

(f) depositing a reflection enhancing material onto the first surface of the substrate such that, in the third region, the reflection enhancing material is deposited onto the cured material and follows the contours of the relief structure; wherein the masking substance impedes the retention (e.g. deposition and/or
5 adhesion) of the reflection enhancing material such that the reflection enhancing material is retained only in areas to which the masking substance was not applied.

By "viewing region" it is meant a gap in the coating layer(s) applied in step (d),
10 within which the relief structure will be viewed in the end product. The viewing region could have the same opacity as its surroundings such that it is not distinguishable in transmitted light. However, in preferred examples the viewing region comprises a window region, i.e. a region of lower opacity than its surroundings.

15 By applying both coating layer(s) which define the viewing region and curable material (forming a security device) and then using a masking substance to define those parts of the substrate in which the reflection enhancing material will be retained, the result is that the coating layer(s), curable material and reflection
20 enhancing material can all be applied in register with one another, whilst still enabling the use of a metal or HRI layer as the reflection enhancing material. As such, the optical quality of the security device formed in the third region by the cured material and reflection enhancing material in combination can be comparable to those of traditional foil-based devices. High registration is
25 achievable because all of the steps which define the end locations of the curable material, reflection enhancing material and viewing region in the coating layer(s) are performed before the step of depositing the reflection enhancing material (during which heating typically takes place), and hence before any warping or distortion or stretch of the substrate occurs.

30 It is therefore preferable that in steps (b), (d) and (e), the respective curable material, coating layers and masking substance are applied in register with one another and advantageously in register with the relief structure formed in step (c).

Moreover, as discussed further below, the use of a masking substance in this way has the benefit that each of the steps defining the end locations of the viewing region in the coating layer(s), the curable material and the reflection enhancing material can be performed using similar or the same type of application techniques (e.g. printing or coating), and hence all can be performed in a continuous, in-line process. This further enhances the achievable registration and simplifies the manufacturing process since all of these application steps can be completed before the deposition step (e.g. metallisation), which may take place separately, e.g. as part of a separate process and potentially on separate apparatus. This may be the final step in the manufacturing process with no need for further application steps, hence reducing the manufacturing process to two key stages.

The viewing region could take a number of different forms, including an interruption in only the coating layer(s) applied to the first or second side of the substrate to reveal the security device, whilst the other side may ultimately be fully coated with opaque material, in which case the viewing region will not be visible in transmission. However, as noted above, in preferred examples, the viewing region defined by the coating layer(s) laid down in step (d) is a window region. This may ultimately be a full window (i.e. no coating layer is provided on either side of the substrate in the window region) or a half window (i.e. coating layer(s) of less than 100% opacity are applied to only one side of the substrate in the window region).

The coating layer(s) which are laid down in step (d) are the layer(s) which define the location, shape and size of the viewing region by means of a gap in those layer(s). In some cases, this will include all of the coating layers which are planned to be applied to the security document. However, in other cases there may be additional coating layer(s) which do not contribute to the definition of the viewing region and in this case such additional layer(s) could be applied during step (d) or at any later stage, including after step (e) or after step (f). For example, where the viewing region is a half window type structure (translucent or non-translucent), the coating layer(s) applied to one side of the substrate may

extend all over the substrate and these could be applied later since no registration between such all-over layer(s) and any other feature is necessary. However in general it is preferable to apply all of the coating layers before step (f) so that all the printing / coating steps are complete before application of the reflection enhancing material. In this way the substrate web does not have to be returned to printing/coating apparatus after reflection enhancing material deposition.

It should also be noted that whilst the coating layer(s) applied in step (d) will generally be applied outside the first region containing the curable material, those coating layer(s) may also overlap that first region, provided that on the first surface, at least part of the first region is left uncovered at the end of step (d) so that it is available for receipt of reflection enhancing material in step (f). Hence, on the first surface of the substrate, the coating layer(s) applied in step (d) will not fully overlap the curable material, but on the second surface of the substrate the coating layer(s) applied in step (d) may extend across the whole first region, e.g. if the viewing region is to be a half-window. In preference, the coating layer(s) define either a window or a "half-window" structure (translucent or non-translucent) on the substrate within which at least part of the curable material is located.

The relief structure could be configured to exhibit any type of optically variable effect, which means that its appearance is different at different viewing angles. In particularly preferred embodiments, the optically variable effect generating relief structure is one which gives rise to a diffractive optical effect, such as a hologram or a diffraction grating. However, it should be appreciated that in other embodiments the relief structure may be a non-holographic optical structure, such as a prismatic structure.

The masking substance could operate according to various different mechanisms, including inhibiting adhesion of the reflection enhancing material to the substrate and/or obstructing deposition of the reflection enhancing material onto the substrate in the first place. Depending on the type of masking substance used, no further steps beyond deposition may be necessary to

achieve the desired result. For instance, the masking substance may repel the reflection enhancing material such that no deposition of the reflection enhancing material occurs in the areas to which the masking substance has been applied. In other cases, there may be some deposition of the reflection enhancing material in these areas. This may become detached subsequently without any positive intervention, but in preferred implementations, the method further comprises, after step (f):

(f1) washing the substrate to remove any residual reflection enhancing material in areas to which the masking substance was applied.

10 The washing may be performed using a liquid (e.g. water) or gaseous (e.g. air jet) substance. Where a liquid is used, preferably the liquid has the capacity to dissolve the print mask (e.g. the mask is soluble within the washing liquid).

In one preferred implementation the masking substance comprises an oil mask adapted such that application of the reflection enhancing material thereto causes degassing of the oil mask, thereby impeding adhesion of the reflection enhancing material to the substrate. Such substances have the benefit that a subsequent removal step (e.g. step (f1)) is typically not required. Examples of suitable oil masks include low molecular weight oils, including silicones, which will boil off in a vacuum environment. US-A-3935334 mentions oil masks in the content of metallised resin films for condenser elements.

In other preferred embodiments, the masking substance comprises a soluble mask, such as soluble ink (comprised of an appropriate binder and pigment combination), which does not adhere strongly to the substrate or can be dissolved by application of a solvent (aqueous or otherwise), thereby impeding adhesion of the reflection enhancing material applied thereto to the substrate. In this case a washing step may be required. Examples of a suitable soluble mask in the form of a heavily pigmented ink are described in WO-A-9913157. Various mechanisms may be adopted but in one example, the soluble mask is configured such that, when coated with a thin deposited layer of reflection enhancing material (e.g. metal) the masking substance creates small holes or discontinuities in the metal film by virtue of the fact that the metal film (typically 15 to 30nm thick) is not thick enough to continuously over coat the pigment

grains in the mask. When immersed in a suitable solvent (preferably water) the solvent enters through these holes, dissolving the pigment such that the overlying metal layer disbands. In order for this mechanism to operate effectively, the pigment grain dimensions are preferably greater than the thickness of the reflection enhancing film. For instance, preferred pigment grain sizes may be in the range of greater than or equal to about 100 nm, and less than 500 nm. The upper limit on this range takes into account that in typical designs the minimum line width of a reflective region will be of the order of 500 nm, and the grain size should be less than this in order to permit adequate resolution of the desired pattern. Other examples of suitable soluble masks are disclosed in US-A-51 42383, EP-A-1 023499 and US-A-3935334.

The use of a soluble mask will be preferred over an oil mask in many cases, since such oils (e.g. low molecular weight oils) will tend to offset, transfer or smear if the substrate web is wound into a roll after printing. As such, the use of oil masks is more suited to processes in which in-line metalisation takes place after the printing or other application steps (i.e. there is no rewind process between printing and metalisation). In contrast, the use of a print soluble mask applied does not impose such limitations. In addition, the vapours produced by degassing of an oil mask can in some circumstances lead to contamination of the optical structure.

The curable material, coating layer(s) and masking substance can be laid down using any appropriate method which enables selective application of the materials to the desired regions of the substrate. In preferred embodiments, in steps (b), (d) and/or (e), the respective curable material, coating layers and/or masking substance are applied using one or more printing technique(s), such as gravure printing, flexographic printing or slotted die coating. Printing techniques are preferred since the materials can be laid down in a precisely controllable manner. Different printing techniques may be used for each of the steps as appropriate for the material in question. However, in particularly preferred embodiments, the same printing technique is used for steps (b), (d) and (e), which simplifies the manufacturing process and apparatus.

As mentioned above, it is especially preferred that at least steps (b), (c), (d) and (e) are performed in a continuous, in-line process. For example, these steps may be carried out at stations along one continuous manufacturing line such that the relative location of the substrate is known between one station and the next.

5 This approach allows particularly high registration to be achieved and also delimits all the printing/application steps from subsequent metallisation (or other deposition) processes.

The deposition of the reflection enhancing material can be achieved using any
10 appropriate deposition technique but generally a non-selective deposition technique will be preferred for simplicity. That is, the technique will result in the deposition of a contiguous layer of the reflection enhancing material across the entire area of the substrate which is exposed to the deposition process. In many cases, this will be the entire first surface of the substrate (although this is not
15 essential). Preferably, the reflection enhancing material is deposited by vacuum deposition, suitable techniques including electron beam vapour deposition, vapour deposition from a resistively heated source (e.g. a boat source), pulsed laser vapour deposition, evaporative vapour deposition and sputtering, as well as chemical vapour deposition methods. Evaporative vapour deposition
20 techniques from resistively heated or electron beam sources are generally preferred.

Preferably, the reflection enhancing material is a metal or alloy, or a material with a refractive index which differs from that of the cured material by at least
25 0.3, more preferably 0.5 (known as "high refractive index (HRI)" materials). That is, the reflection enhancing material is laid down as a contiguous layer of the selected material (or as multiple spaced portions each having such a contiguous layer). This should be contrasted with materials such as metallic inks, which comprise a dispersion of reflective particles in a binder, the reflective (particle)
30 material itself therefore not forming a contiguous layer. Examples of suitable metals or alloys include aluminium, copper, nickel, chrome, aluminium-copper alloys, silver, gold, etc. By "high refractive index" (HRI) materials, we mean materials having an index of refraction which exceeds that of the transparent base layer by a numerical value of preferably 0.5 or more. Since the refractive

index of the base layer will typically fall in the range of 1.45 - 1.55, then a high refractive index material will be one with an index of preferably 2.0 or more. In practice high refractive index materials with good visual transparency will have an index in the range 2.0 to 2.5. Examples of suitable HRI materials include
5 zirconium dioxide and zinc sulphide and titanium dioxide

In particularly preferred embodiments, the curable material is a transparent curable material. This enables the optical effect generated by the relief structure to be observed through the substrate and hence, if the opposite side of the relief
10 structure is also visible and both sides of the reflection enhancing material conform to the relief, the optical effect is exhibited by both sides of the device. This results in a security device with a strong visual impact and hence increased security level.

15 The curable transparent material may be of a type which can be cured by the application of any form of energy, such as heat. However, in most preferred embodiments, the curable transparent material is radiation-curable, preferably UV-curable, and in step (c) the curing comprises exposing the formed curable material to curing radiation, preferably UV radiation. The application of radiation
20 can generally be more accurately controlled than that of heat, e.g. through the use of appropriately directed radiation sources and/or masks. Additionally the cross-linking action is generally much more rapid in UV curable systems compared to thermal cure systems leading to a more accurate relief forming process. Finally it is often very desirable to limit or strongly minimise thermal
25 distortion of the substrate and in such cases a UV cure may be the only suitable cross-linking approach. It should be noted that radiation wavelengths other than UV may be used. However, it is preferred that the substrate is at least semi-transparent to the curing energy (e.g. to the relevant radiation wavelength(s)), so that the energy can be applied to the curable material through the substrate.
30 Polypropylene, for example, is generally transparent to UV wavelengths.

As mentioned above, the curable material is preferably at least visually semi-transparent (i.e. transmits wavelengths in the visible range) such that the optical effect of the device can be viewed through the material. However, the material

need not transmit all visible wavelengths equally and in preferred examples, the material further comprises an optically effective substance, preferably a visible colourant, a luminescent, phosphorescent or fluorescent material. This further enhances the security level of the device and can be used to cause the optically
5 variable effect to be seen in a different colour when viewed from one side of the device (through the curable material) as opposed to the other. Such optically effective substances could additionally or alternatively be disposed in any of the other layers of the device, including the substrate and/or the reflection enhancing layer.

10

In many implementations, a single type of curable material will be applied in the first region. However, in some preferred embodiments, step (b) comprises applying two or more curable materials to the first region of the substrate in a pattern, one or more of the curable materials comprising an optically effective
15 substance such that the two or more curable materials have different optical characteristics, preferably visibly different under at least visible or non-visible illumination. By providing a pattern which is detectable either to the naked eye or to a machine in this layer, the security level of the device is further increased. If two or more curable materials are provided it is preferred that they are each
20 adapted to be cured by the same type of curing energy and most advantageously at the same rate as one another, so that both are cured simultaneously in step (c).

In step (c) the partially cured transparent material and the layer of reflection
25 enhancing material can be formed by any appropriate method but preferably the layers are embossed with a die carrying the relief structure, wherein the die advantageously forms part of an embossing roller. If multiple devices are to be formed on a substrate web (later to be divided into individual security documents each carrying one of the devices), the embossing roller may preferably carry the
30 relief structure in the form of a repeating pattern. The repeat periodicity is preferably matched to that of the document repeat length and/or width.

In step (c), the curable material may be cured simultaneously with and/or subsequently to forming of the relief structure in the surface of the curable

material. For example, if the embossing roller is opaque (e.g. metal), curing can occur at the point of impression with radiation being transmitted through the substrate, for instance using a transparent quartz nip roller opposing the embossing roller. Alternatively curing can take place just after the resin leaves
5 the impressing nip, in which case the radiation can be applied through the substrate or from the opposite side.

Preferably, the one or more coating layers applied in step (d) comprises one or more opacifying layers. This step is particularly relevant where the substrate is to
10 become the substrate of a polymer banknote. The coating may be applied to one or both sides of the substrate and as mentioned above, is preferably omitted across the (third) region in which the security device is formed on both sides, although in some cases it may be applied across all of some of the region on the side of the substrate opposite from that to which the curable material is applied.
15 This can lead to the appearance of a "half window" effect and/or conceal one or more portions of the device when viewed through the substrate. Opacifying layers typically comprise a binder containing a white (or other coloured) pigment.

Preferably the method further comprises, after step (d) or step (f), printing a
20 graphics layer onto the one or more coating layers. The graphics layer may include for example background patterns such as those typically seen on banknotes, optionally incorporating fine line patterns, guilloches and other security features, information such as denomination and other standard document data, and/or printed features which uniquely identify or personalise the
25 document, such as a serial number in the case of a banknote or details of the holder in the case of an identity document. Most preferably, such graphics and other features will be printed onto the document after application of the reflective material.

30 Advantageously, the method further comprises, prior to step (b) or step (d), treating the surface of the substrate to increase adhesion between the substrate and the curable material and/or the coating layer(s), preferably by the application of a primer substance or corona treatment. This can for example raise the surface of the substrate making it more receptive to the subsequent application

of the curable material and/or the coating layer(s). Similarly in preferred embodiments, the method further comprises, after step (c), treating the formed surface of the cured material to increase adhesion between the cured material and the reflection enhancing material, preferably by plasma or corona treatment.

5

As already mentioned, the method can preferably be implemented as a web-based process with multiple security devices (i.e. "third regions") being formed on a substrate which is then divided such that each device is located on a separate piece of substrate. Hence, preferably the method further comprises, after step (f), cutting the substrate into individual security. Typically this would also take place after the optional step of printing a graphics layer has been performed.

Preferably, the first, second and/or third regions define respective indicia such as a character, letter, number, symbol, graphic element or the like, the respective indicia preferably being different. This can be used to create a complex security device with a correspondingly high security level. In other preferred embodiments, the first and second regions, and hence the third region, are the same such that the reflection enhancing material is retained across the whole of the region in which the curable material is present. In yet further alternative preferred embodiments, the third region is contained within the first region, such that the reflection enhancing material is retained across less than the whole of the region in which the curable material is present. The shape of the viewing region (preferably a window region) may also or alternatively define such indicia.

25

Advantageously, the substrate is transparent and preferably comprises a polymer such as polypropylene (PP), orientated polypropylene (OPP), biaxially orientated polypropylene (BOPP) polyethylene terephthalate (PET), polyethylene, polyamide, polycarbonate, or polyethylene naphthalate (PEN).

30

Preferably, the security document is a banknote, a polymer banknote, a hybrid paper/polymer banknote, an identity document, a passport, an identification card, a cheque, a visa, a certificate, or a stamp.

The invention further provides a security document manufactured in accordance with the above method, wherein the security document is preferably a banknote, a polymer banknote, a hybrid paper/polymer banknote, an identity document, a passport, an identification card, a cheque, a visa, a certificate, or a stamp.

5

Also provided is a security document, comprising:

a polymeric substrate having first and second surfaces;

a cured material disposed in a first region of the substrate on its first surface, the cured material having an optically variable effect generating relief structure formed in its surface distal from the substrate;

10

a reflection enhancing material disposed on at least part of the cured material, the reflection enhancing material following the contours of the relief structure, wherein the reflection enhancing material is a metal or alloy, or a high refractive index (HRI) material; and

15

one or more coating layers disposed on the first and/or second surface(s) of the substrate, the coating layer(s) being absent on at least one of the first or second surfaces across all or part of the first region to define a viewing region;

wherein the cured material, the reflection enhancing material and the viewing region defined by the one or more coating layers are registered to one another.

20

For the reasons given above, in conventional devices on polymer-type security documents it has not been possible to achieve registration between the material in which the relief is formed, the reflection enhancing material and the viewing region (e.g. window or half-window) in the coating layer(s). High registration is beneficial since each document so produced will have a consistent construction and appearance, making counterfeit documents readily identifiable. Preferably, the security document is manufactured in accordance with the method described above, and can have any of the features resulting from any of the method steps described above.

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The security document is preferably a banknote, a polymer banknote, a hybrid paper/polymer banknote, an identity document, a passport, an identification card, a cheque, a visa, a certificate, or a stamp.

The present invention further provides a plurality of such security documents, wherein the cured material, reflection enhancing material and viewing region in the one or more coating layers have substantially the same positions relative to one another in each of the plurality of security documents.

Examples of security devices, security documents and methods for their manufacture will now be described with reference to the accompanying drawings, in which:

- 10 Figure 1 is a schematic cross-section through a first embodiment of a security document equipped with an exemplary security device;
Figure 2 is a plan view of the security document of Figure 1;
Figure 3 is a flowchart depicting selected steps of a first embodiment of a method for manufacture of a security document;
- 15 Figures 4a, b, c, d, e and f depict components of a second embodiment of a security document at various stages of manufacture;
Figures 5a and b schematically depict an embodiment of apparatus suitable for manufacture of a security document;
Figure 6 is a schematic cross-section through a further embodiment of a security document exhibiting a further embodiment of a security device;
- 20 Figure 7 is a plan view of the security document of Figure 6; and
Figures 8, 9 and 10 depict further embodiments of security documents in cross-sectional views.

- 25 The present description will focus on security documents provided with integral security devices having optically variable effect generating relief structures which give rise to diffractive optical effects, such as holograms or diffraction gratings. However, it should be appreciated that in other embodiments the relief structure may be a non-holographic micro-optical structure, such as a prismatic structure.
- 30 Examples of prismatic structures suitable for the security devices of the sort presently disclosed include, but are not limited to, a series of parallel linear prisms with planar facets arranged to form a grooved surface, a ruled array of tetrahedral, an array of square pyramids, an array of corner cube structures, and an array of hexagonal faced corner cubes. Another preferred type of micro-

optical structure is one which functions as a micro lens, including those that refract light at a suitably curved surface of a homogeneous material such as plano-convex lenslets, double-convex lenslets, plano-concave lenslets and double-concave lenslets. Other suitable micro-optical structures include
5 geometric shapes based on domes, hemispheres, hexagons, squares, cones, stepped-structures, cubes or combinations thereof.

Figure 1 depicts a first embodiment of a security document 1, such as a banknote, cheque, visa, passport, identification card etc., which is provided with
10 a security device 10. The security document 1 is formed based on a transparent substrate 2, such as a polymer film, which also forms a substrate of the security device 10. The security device 10 is considered to be integrally formed with the security document 1. In the case of Figure 1, the substrate 2 is typically formed of a visually transparent polymer such as polypropylene, although other flexible
15 polymeric films suitable include polyethylene terephthalate (PET), polyethylene, polyamide, polycarbonate, polyvinylchloride (PVC), polyvinylidenechloride (PVdC), polymethyl methacrylate (PMMA), or polyethylene naphthalate (PEN).

The substrate 2 carries one or more coating layers on one or both of its surfaces
20 which increases the document's opacity in the covered regions and/or provides a background to printed graphics. In the present example, the substrate 2 is coated with opacifying layers 3 and 4, which layers carry printed graphics 5a and 5b. In the present embodiment, both layers 3 and 4 are provided on both sides of the security document 1, but in other cases the layers may be provided on
25 only one side or the other. Further, here the coatings 3 and 4 are omitted on both sides of the documents to define a viewing region 20 within which the security device 10 is located. In this case, the viewing region 20 is a window region having a lower opacity than its surroundings, and will therefore be referred to hereinafter as a "window", although this is not essential as described
30 below. The structure depicted in Figure 1 is a "full-window". In other cases, the layers 3, 4 (and 5) may be omitted in the window region 20 only on one side of the document, with one or more of the layers 3, 4 and 5 continuing over all or part of the window 20 on the other side of the document. This can be used

either to create a so-called "half window" effect or to prevent viewing of the device through the document, as discussed further below.

5 Inside the window 20, on the first surface 2a of substrate 2 (here the upper surface, facing observer A) the security device 10 is disposed. A curable transparent material 11, such as a radiation curable resin or a thermoplastic material containing a curable cross-linking agent is disposed on the substrate 2 across a first region F^{\wedge} . The curable transparent material 11 carries a reflection enhancing material 12, such as a metal film (e.g. aluminium or copper) or a HRI layer (e.g. zinc sulphide). The curable transparent material 11 has been formed so as to follow the contours of a surface relief 13 defining an optically variable effect generating structure, such as a hologram or diffraction grating (as discussed further above), and the reflection enhancing material 12 follows the contours of the relief. The reflection enhancing material 12 is present across a second region R_2 , which at least overlaps with the first region R_1 and in this case is the same as region F^{\wedge} . The parts of the first and second region which overlap define the third region R_3 , in which the reflection enhancing material is deposited on the formed curable material to form security device 10. The curable material 11, reflection enhancing material 1 and window 20 defined by coating layers 3, 4 are substantially in register with one another, such that their relative locations do not vary substantially between one banknote and another of the same type. For instance, the position tolerance of the curable material 11, reflection enhancing material 1 and coating layers 3, 4 may be as low as +/- 100 to 200 microns or exceptionally less from one document to the next.

25 In this example, the security document is completed by the application of a protective varnish or lacquer 19 (also preferably transparent) which covers the security device and, here, also a portion of the surrounding window region 20 and optionally coatings 3, 4 and 5. In some cases the whole first surface 2a of the security document 1 may be covered with the protective coating 19. The coating 19 could be coloured or multicoloured or contain a security substance, e.g. a fluorescent, luminescent or phosphorescent material.

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It will also be noted that, in this example, the transparent curable material 11 is not applied directly to the transparent substrate 2, but rather a primer layer 9 exists between the substrate 2 and the curable transparent material 11. The primer layer 9 improves adhesion between the substrate 2 and the transparent curable material 11. However its use is optional. In further alternative embodiments, the substrate 2 may be corona treated in order to improve adhesion between it and curable material 11.

Figure 2 shows a plan view of the security document of Figure 1 as viewed by observer A. As previously described, the document 1 carries graphic layer 5 across much of its surface which (together with underlying coating layers 3 and 4) is omitted in the region of window 20. Inside window 20, the security device 10 extends across the region R_3 which here has the form of a sun-shaped symbol. In other cases, the region R_3 may define an alternative indicia such as a letter, number or graphic, and the region R_3 could extend to cover the whole window 20 (although this is less preferred). The optically variable effect generated by relief structure 13 is visible across the whole of sun-shaped region R_3 (assuming the relief structure 13 itself extends across the whole of the region). Outside the region R_3 , the window 20 is transparent and optically invariable. It should be noted that in this case when the security document is viewed from the opposite side of the substrate (i.e. from the position of observer B depicted in Figure 1) its appearance will be substantially identical as that shown in Figure 2 since here the same surface relief 13 in reflective layer 12 will be viewed through transparent curable material 11.

Figure 3 depicts steps in a first embodiment of a method suitable for forming a security device of the sort described with respect to Figures 1 and 2. To illustrate exemplary implementations of the steps, Figures 4(a) to (f) show another embodiment of a security document at various stages during its manufacture.

As will be discussed below, the initial steps of the method may be carried out in a different order from that shown in Figure 3.

In step S101, a curable material 11 is applied to the first surface 2a of substrate 2, e.g. using any appropriate coating or printing techniques, preferably gravure, and the resulting structure is shown in Figure 4a. As described previously, in practice the substrate may be treated prior to application to curable material 11, either by applying a primer layer 9 or by corona treatment to raise the surface of the substrate material, for example. The curable material is applied across a first region R_1 which may define indicia. The curable material could be a radiation curable resin or a thermoplastic containing a curable hardening agent. For instance, a curable resin may typically be one of two types: a) Free radical cure resins which are unsaturated resins or monomers, prepolymers, oligomers etc. containing vinyl or acrylate unsaturation for example and which cross-link through use of a photo initiator activated by the radiation source employed e.g. UV; or b) Cationic cure resins in which ring opening (e.g. epoxy types) is effected using photo initiators or catalysts which generate ionic entities under the radiation source employed, e.g. UV. The ring opening is followed by intermolecular cross-linking. The radiation used to effect curing will typically be UV radiation but could comprise electron beam, visible, or even infra-red or higher wavelength radiation, depending upon the material, its absorbance and the process used. Alternative thermoplastic lacquers such as PMMA-based resins, acrylic resins or vinyl/styrene copolymers could be used with added curing agent.

In step S103, a relief structure 13 is formed into the surface of the curable material 11 so as to define an optically variable effect generating structure such as a hologram or a diffraction grating. This may be achieved for example by impressing the curable material using an embossing roller. The material is cured, for example by exposure to an appropriate curing energy such as heat or radiation (preferably UV radiation) in order to fix the relief structure in place such that the material cannot relax or exhibit viscous flow. Any known cast-cure process can be used to perform step S103 and it should be noted that curing may take place simultaneously with and/or subsequently to the casting of the relief into the material. Figure 4b shows the formed relief 13 in material 11 and irradiation of the material with curing energy E (e.g. UV radiation) through substrate 2.

In step S105, one or more coating layers are applied to the substrate defining a viewing region (e.g. a window region) containing all or part of the region in which curable material 11 has been laid down. In the example depicted in Figure 4c, two coating layers 3 and 4 in the form of opacifying layers have been laid down on the first surface 2a of the substrate. In this example, both layers are provided only outside the curable material region R_1 , but in other cases there could be an overlap. Further, in this example both coating layers 3, 4 are provided on the first surface 2a of the substrate 2. In other cases, the coating layer(s) may alternatively or additionally be disposed on the opposite surface 2b of the substrate. If coating layer(s) are to be provided on both sides of the substrate, the coating layer(s) may be applied to each side simultaneously or sequentially.

It will be appreciated that the same structure shown in Figure 4c can be obtained in a number of different ways. In particular, as illustrated by the dashed line arrows in Figure 3, step S105 in which the coating layer(s) are applied may be carried out prior to the application of the curable material 11 (i.e. before step S101). Alternatively, the coating layer(s) could be applied after the curable material 11 has been applied but before it is formed and cured (i.e. between steps S101 and S103). It would also be possible to apply various different coating layers at different stages during this part of the process, for example a first opacifying layer 3 could be applied before step S101 and a second opacifying layer 4 could be applied after step S103.

After the curable material 11 and coating layer(s) defining the viewing region have been applied to the substrate, and the curable material has been formed and cured, in step S107 a masking substance 15 is applied to the first surface 2a of the substrate, as shown in Figure 4d. The masking substance 15 is laid down across areas of the substrate in which the reflection enhancing material is ultimately not desired and, as such, the masking substance 15 can comprise any material which impedes adhesion of the reflection enhancing material 12 to the underlying substrate (and/or to any intervening layers, such as layers 3 and 4 in this example). In one preferred embodiment, the masking substance 15 comprises an oil mask which de-gases when a material is laid down on top of it,

thereby preventing its adhesion. In another preferred embodiment, the masking substance 15 comprises a soluble mask, such as soluble ink. One exemplary type of soluble ink is heavily pigmented ink as disclosed in WO-A-99-13157. Mechanisms by which soluble masks operate vary but in one example, the pigment grains in the mask are sufficiently large that when a layer of metal or other reflection enhancing material is deposited on top of the ink, holes are formed through the deposited layer. As such, during subsequent washing with a solvent, the fluid can pass through the deposited layer, reaching and dissolving the pigment. This leads to detachment of the reflection enhancing material from the substrate in the regions where the soluble mask is present. Further examples of suitable soluble masks are given in US-A-51 42383, US-A-3935334 and EP-A-1 023499.

In order that the reflection enhancing material 12 can be deposited onto and strongly bond to at least part of the relief structure 13, the application of masking substance 15 excludes a second region R_2 of the substrate, which second region R_2 includes at least part of the first region R_1 in which the cured material 11 carrying the relief structure is present. In the example depicted in Figure 4d, the second region R_2 is coincident with the first region R_1 , but this is not essential.

With the masking substance 15 in place, in step S109, the reflection enhancing material is deposited onto the first surface 2a of the substrate 2 to form a layer of reflection enhancing material 12 which extends over the cured material 11 and neighboring regions of the substrate, including portions covered by masking substance 15 as shown in Figure 4e. In practice, depending on the nature of masking substance 15, in fact the reflection enhancing material 12 may not settle on the masking substance. For example, if the masking substance de-gases upon deposit of the reflection enhancing material 12, the deposition step S109 may result directly in the structure shown in Figure 4f, in which the reflection enhancing material is present only on the cured material 11. In other cases, some residual reflection enhancing material 12 may remain on the masking substance 15 in which case a removal step, such as washing step S111, may be performed. This may involve for example washing the surface of

substrate 2 with a liquid (e.g. water) or a gas, such as an air jet. This causes detachment of the reflection enhancing material 12 from the substrate in the areas where masking substance 15 is present, resulting in the same final structure shown in Figure 4f. The region of the cured material 11 to which the reflection enhancing material 12 is applied (i.e. the overlapping parts of regions R_1 and R_2 , termed the third region, R_3) exhibits the desired optically variable effect.

The reflection enhancing material 12 deposited in step S109 is preferably a contiguous film of a suitable reflective material, such as a metal or alloy or an HRI material, so as to achieve high quality optical replay. The material is preferably deposited by a non-selective method, such as vapour or vacuum deposition, in which the whole surface of the substrate that is exposed to the process will be coated with the material (as opposed to a selective application process such as printing). For example, the material may be deposited by a physical vapour deposition process such as evaporative deposition or sputtering, or a chemical vapour deposition process.

In contrast, the previously laid down components (i.e. the curable material 11, coating layers 3 and 4 and masking substance 15) are laid down at controlled locations using preferably a printing technique such as gravure, intaglio, lithographic printing etc., so that the extent and position of each can be precisely controlled. Preferably, the printing or other application techniques used in steps S101, S103, S105 and S107 are performed in register with one another such that the curable material 11, coating layers 3 and 4 and masking substance 15 (and therefore the ultimate position of reflection enhancing material 12) are registered to one another. That is, on a series of like documents produced in the same way, the relative locations of these components of the documents will be substantially identical. Particularly high registration can be achieved by performing steps S101, S103, S105 and S107 in an inline process with, for example, substrate 2 travelling as a web between stations at which each of the steps is carried out. In this way, the positioning of the substrate 2 relative to each of the stations is known and can be controlled. For example, if the curable

material 11, coating layers 3 and 4 and masking substance 15 are each applied by gravure, registration tolerances of +/- 100 to 200 microns are achievable.

5 An example of apparatus suitable for manufacturing a security document of the sort described above will now be described with reference to Figures 5a and 5b. It should be noted that the exemplary apparatus depicted in Figure 5 is suitable for implementing the method as a continuous web-based technique but in other (less preferred) examples, the documents could be made using batch processing methods.

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As mentioned above, the steps of applying the curable material, forming the relief and curing, applying the one or more coating layers and applying the masking substance are preferably carried out in an inline process, and Figure 5a shows an example of suitable apparatus for such a process. Subsequent steps involving deposition of the reflection enhancing material can be carried out as continuation of the process or in a separate manufacturing line. Since all of the printing or other application type steps for which accurate registration is desirable are carried out before the steps involving deposition of the reflection enhancing material, the method lends itself well to carrying out manufacture in two distinct phases and in this example these are reflected by the division between Figures 5a and 5b.

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Thus, Figure 5a depicts an exemplary apparatus 30 for carrying out steps S101 to S107 of the method described with respect to Figures 3 and 4. The substrate 2, such as a transparent polymer film, is supplied from a reel 31. At a first station 32, a curable material 11 is applied to the substrate 2 preferably over discrete regions R_1 (although in other cases the region R_1 may effectively cover the whole substrate 2). In this example, the curable material 11 is a radiation curable material. The station 32 may comprise for example a print roller 32a and an opposing roller 32b. The substrate 2 is then conveyed to second station 33 where a relief structure 13 is formed. Here, the station 33 comprises a rotary embossing roller 33a carrying a repeating pattern of the desired relief structure 13, and opposing roller 33b such as a transparent quartz nip roller. The relief 13 is impressed into the curable material 11 which is simultaneously exposed to

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curing energy E, such as UV radiation. In this example, the radiation source E is disposed within the transparent nip roller 33b. As such, curing takes place at the point of impression of the relief structure 13 into the curable material. However, in other examples, radiation source E may be located just after the web leaves the impressing nip, e.g. between rollers 33a and 33b.

The web, now carrying a series of cured regions 11 each having an impressed surface relief 13, now passes to a third station 34 at which one or more coating layers (such as 3 and 4 depicted in previous Figures) are applied to the substrate 2 to define a viewing region within which at least part of the cured material is located, on one or both sides of the substrate 2. Station 34 may comprise for example a print roller 34a and an opposing roller 34b. In practice, more than one such station may be provided if multiple coating layers are to be applied.

At a fourth station 35, a masking substance 15 is applied to the first surface 2a of the substrate 2, so as to mask off areas in which reflection enhancing material is not desired. Thus, the area to which the masking substance 15 is applied excludes a second region R_2 at least partially overlapping with the cured surface relief regions. The printing/application steps S101 to S107 are thus complete and the intermediate product so-produced may then be wound on to a reel 36 for onward processing at a later time or on a separate apparatus. Alternatively, the web may continue directly to apparatus of the sort described for example with respect to Figure 5b.

Thus, Figure 5b depicts exemplary apparatus for carrying out deposition of reflection enhancing material and an optional washing step. Here, reel 41 supplies the substrate 2 in the form of the intermediate product resulting from the manufacturing stages already described. The web is conveyed through a fifth processing station 42 which in this example comprises a vapour deposition chamber 42a for depositing reflection enhancing material such as metal or a HRI material on to the first surface 2a of the substrate. Typically, the reflection enhancing material may be deposited across the full width of the web as it passes through the chamber.

As discussed above, depending on the nature of the masking substance 15, no further processing steps may be necessary. In other cases, a step of removing residual reflection enhancing material from regions in which it is not desired is useful and in this case the web may be conveyed through a sixth processing station 43, here comprising a washing chamber 43a in which the first surface of the substrate is subjected to washing, e.g. by passing the web through a fluid bath or directing air jets onto the surface of the web. The completed web may then be collected on a reel 44.

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Optional onward processing steps will depend on the nature of the security document in question but may comprise for example one or more further printing steps (e.g. application of further coating layer(s) and/or graphics layer 5) and/or cutting of the web into individual security documents each carrying one security device manufactured in the above described manner. The apparatus may also include additional stations for carrying out optional steps such as surface treatment of the substrate 2 and/or cured material 11. For example, a station may be provided upstream of station 32 for treating the substrate 2 so as to improve adhesion of the curable material and/or coating layers to its surface. This may be achieved for example by applying a print receptive primer such as layer 9 shown in Figure 1 or carrying out corona treatment. Similarly, a treatment station may be inserted at any stage downstream of station 33 for treating the surface of cured material 11 prior to application of the reflection enhancing material, e.g. by plasma or corona treatment.

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As mentioned above, the application of the curable material and the application of the one or more coating layers defining the viewing region may be carried out in the opposite order to that depicted in Figure 5a, in which case the relevant processing stations will be rearranged as appropriate.

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A further embodiment of a security document 1 comprising an integral security device 10' will now be described with reference to Figures 6 and 7. Here, the construction of security document 1, including substrate 2, coating layers 3 and 4 and print 5 is the same as discussed with respect to Figures 1 and 2, and like

features are identified using the same reference numbers. The security device 10' is formed using the same technique as described above. As such, a reflection enhancing material 12 is disposed on cured material 11 and follows a surface relief 13 defining an optically variable effect generating structure. In this example, reflection enhancing material 12 does not cover the whole region R_1 in which the cured material 11 is present, but rather (as shown best in the plan view seen by observer A, shown in Figure 7), only a portion thereof. Here, the cured material 11 covers a region R_1 having the form of a six-pointed star shape whilst the reflection enhancing material 12 is provided only across an area R_2 within region R_1 , having the shape of an arrow symbol. The region R_2 is that region omitted by the coverage of masking substance 15 during manufacture. In this case the optically active region R_3 therefore shares the same bounds as R_2 .

The regions R_1 and R_3 preferably define different indicia. If the cured material 11 is clear and colourless, the star-shaped region R_1 will not be visible to the observer. However, in this embodiment the cured material 11 comprises an optically effective substance such as a colorant, making it visible to observers A and B. The colorant will also have the effect of causing the device to have different optically variable appearances from the point of view from observer A and observer B, since observer A will see the optical effect through colourless protective lacquer 19, meaning that the colour of the effect will be determined solely by that of reflection enhancing material 12, whereas observer B will see the optically variable effect through the cured material 11 which will therefore impose its colour onto the optically variable effect.

The optically effective substance in the cured material 11 could comprise any visible colorant and/or any non-visible but machine detectible substance and/or a substance which only becomes visible under certain conditions, such as UV illumination. For example, the optically effective substance could be a luminescent, fluorescent or phosphorescent material.

The reflection enhancing material 12 and/or substrate 2 may also comprise an optically effective substance such as these.

The security level of the document can be further increased by forming the layer 11 from two or more transparent curable materials, and this is the case in the embodiment depicted in Figures 6 and 7, where one portion of region R_1 is formed of a first curable material 11a and another portion of the region is formed with a second curable material 11b. The two or more curable materials preferably comprise different optically effective substances so that a pattern formed by the two curable materials is visible to a human observer and to a machine. It is preferred that where two or more materials are provided in this way, they are each responsive to the same form of curing energy so that both can be cured simultaneously in step S103.

Figures 8, 9 and 10 depict cross-sections through three further embodiments of security documents illustrating further optional features.

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In the embodiments described so far, the substrate 2 of the document is transparent and this is preferred in order to provide document with features such as see-through windows or translucent half-windows which have a high recognition value and thus increase the security level of the document. However, this is not essential and the polymeric substrate could be translucent or opaque and this is the case in the Figure 8 embodiment. In this case, the security device 10" is only designed to be viewed from one side (that of observer A) and thus the coating layers 3b, 4b and print 5b on the second surface 2b of the substrate 2' may be continuous in the region of the security device 10". Here, the viewing region 20' has the same opacity as its surroundings and a similar result could be achieved using a transparent or translucent substrate 20 in combination with all-over coating layers 3b, 4b of sufficiently high opacity. The security device 10" is constructed in substantially the same manner as described above. In this example however, the second region R_2 across which the masking substance 15 is omitted during manufacture extends beyond the edges of the first region R_1 in which the curable material 11 is deposited. Thus, as shown in Figure 8 in the resulting security document the reflection enhancing material 12 may extend beyond the perimeter of the cured material 11 carrying

the surface relief 13. In this case, the optically active third region R_3 is equal to the first region F^{\wedge} .

In the previous embodiments, all of the coating layers 3, 4 which are intended to be applied to the security document are applied prior to deposition of the masking substance and reflection enhancing material. However this is not essential since only those coating layers which contribute to the definition of the viewing region 20 need be applied at that time. Figure 9 shows an exemplary embodiment in which it is advantageous to apply certain coating layers prior to application of the reflection enhancing material, and others after. Here, the security document 1" is provided with a security device 10" which is designed to be viewed only through the substrate 2 (which must therefore be transparent), through viewing region 20" from the position of observer B. The curable material 11 is also transparent and the optically variable effect generated by relief structure 13 can thus be viewed through the curable material 11 and the transparent substrate 2. In this case, the security device is manufactured using the same method as described above but, in the process step corresponding to step S105 shown in Figure 3, only coating layers 3b and 4b are applied (to the second surface of the substrate 2), since it is only these layers which define viewing region 20". At this stage, no coating layers are applied to the first surface of the substrate 2 which is to carry curable material 11. Thus, the relief structure 13 remains available for deposition of the reflection enhancing material 12. After the reflection enhancing material 12 has been applied to the desired region, further coating layers 3a, 4a are applied all-over the first surface of the substrate, including over security device 10". The coating layers 3a, 4a may or may not be of the same number and/or composition as the coating layers 3b, 4b. If the coating layers 3a, 4a are translucent, the viewing region 20" will act as a half-window, becoming distinguishable from its surroundings when viewed in transmitted light. Alternatively, if the coating layers 3a, 4a are sufficiently opaque (in combination), the viewing region may not have the characteristics of a window, exhibiting the same opacity as its surroundings and hence not being distinguishable in transmitted light.

In the Figure 9 example, since the coating layers 3a, 4a are continuous all over the surface of the substrate, there is no need for accurate registration between those layers and other features of the document, hence the ability to apply those layers after deposition of the reflection enhancing material. The same would
5 apply to any other coating layers which do not contribute to the definition of the viewing region 20, e.g. partial coating layers which are only applied in areas sufficiently spaced away from the viewing region. However in general it is preferred to apply as many of the coating layers as possible prior to deposition of the reflection enhancing material, and it is only those which ultimately cover the
10 region(s) of the relief structure 13 on the first side of the substrate 2 (such as layers 3a, 4a in Figure 9) for which this is not possible.

Figure 10 shows a further example of a security document 1" in which the security device 10 is identical to that discussed with respect to Figure 1. In this
15 case, the security device 10 is located in a "half window" region 20" of the document, with coating layers 3 and 4 on the first surface of the document being omitted across the region in which the security device is present whilst the coating layers 3b and 4b are continuous across the same region on the opposite side of the substrate. In this way, the optical effect of security device 10 is only
20 clearly visible from one side of the document (that of observer A), but depending on the opacity of layers 3b and 4b, from the opposite side the half window region may be apparent as a relatively light or translucent region, and the optical effect generated by relief 13 may also be visible to an extent. To form this type of structure, the coating layers 3a, 4a will be laid down prior to deposition of the
25 reflection enhancing material, but the coating layers 3b, 4b could be laid down at the same time or at a later stage. This is because only coating layers 3a, 4a define the viewing region (half-window) 20" whilst layers 3b, 4b are all-over and so do not require accurate registration.

CLAIMS

1. A method of manufacturing a security document, comprising:
- (a) providing a polymeric substrate having first and second surfaces;
- 5 then performing the following steps (b), (c) and (d) in any order:
- (b) applying a curable material to a first region of the substrate on its first surface;
- (c) forming the curable material such that its surface distal from the substrate follows the contours of an optically variable effect generating relief structure and
- 10 curing the curable material such that the relief structure is retained by the cured material;
- (d) applying one or more coating layers to the first and/or second surface(s) of the substrate to define a viewing region, the coating layer(s) being absent at least on the first surface across all or part of the first region;
- 15 then:
- (e) applying a masking substance to the first surface of the substrate, excluding at least a second region which includes at least part of the first region, the overlapping portions of the first and second regions defining a third region;
- (f) depositing a reflection enhancing material onto the first surface of the
- 20 substrate such that, in the third region, the reflection enhancing material is deposited onto the cured material and follows the contours of the relief structure; wherein the masking substance impedes the retention of the reflection enhancing material such that the reflection enhancing material is retained only in areas to which the masking substance was not applied.
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2. A method according to claim 1, wherein step (f) further comprises:
- (f1) washing the substrate to remove any residual reflection enhancing material in areas to which the masking substance was applied.
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3. A method according to claim 1 or claim 2, wherein the masking substance comprises an oil mask adapted such that application of the reflection enhancing material thereto causes degassing of the oil mask, thereby impeding adhesion of the reflection enhancing material to the substrate.

4. A method according to claim 1 or claim 2, wherein the masking substance comprises a soluble mask which does not adhere strongly to the substrate, or can be dissolved by application of a solvent, thereby impeding adhesion of the reflection enhancing material applied thereto to the substrate.

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5. A method according to any of the preceding claims wherein in steps (b), (d) and (e), the respective curable material, coating layers and masking substance are applied in register with one another and preferably in register with the relief structure formed in step (c).

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6. A method according to any of the preceding claims wherein in steps (b), (d) and/or (e), the respective curable material, coating layers and/or masking substance are applied using one or more printing technique(s), such as gravure, flexographic or slotted die, preferably the same printing technique.

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7. A method according to any of the preceding claims, wherein at least steps (b), (c), (d) and (e) are performed in a continuous, in-line process.

8. A method according to any of the preceding claims, wherein in step (f) the reflection enhancing material is deposited by a non-selective deposition technique.

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9. A method according to any of the preceding claims, wherein in step (f) the reflection enhancing material is deposited by vapour deposition.

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10. A method according to any of the preceding claims, wherein the reflection enhancing material is a metal or alloy, or a material with a refractive index which differs from that of the cured material by at least 0.3.

11. A method according to any of the preceding claims, wherein the curable material is a transparent curable material.

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12. A method according to any of the preceding claims, wherein the curable material is a radiation-curable material, preferably UV-curable, and in step (c)

the curing comprises exposing the formed curable material to curing radiation, preferably UV radiation.

13. A method according to any of the preceding claims, wherein the curable material comprises an optically effective substance, preferably a visible colourant, or a luminescent, phosphorescent or fluorescent material.

14. A method according to any of the preceding claims, wherein in step (c), the curable material is formed by embossing with a die carrying the relief structure, wherein the die preferably forms part of an embossing roller.

15. A method according to any of the preceding claims, wherein in step (c), the curable material is cured simultaneously with and/or subsequently to forming of the relief structure in the surface of the curable material.

16. A method according to any of the preceding claims, wherein the one or more coating layers applied in step (d) comprises one or more opacifying layers.

17. A method according to any of the preceding claims, further comprising, after step (d) or step (f), printing a graphics layer onto the one or more coating layers.

18. A method according to any of the preceding claims, further comprising, prior to step (b) or step (d), treating the surface of the substrate to increase adhesion between the substrate and the curable material and/or the coating layer(s), preferably by the application of a primer substance or corona treatment.

19. A method according to any of the preceding claims, further comprising, after step (c), treating the formed surface of the cured material to increase adhesion between the cured material and the reflection enhancing material, preferably by plasma or corona treatment.

20. A method according to any of the preceding claims, further comprising, after step (f), cutting the substrate into individual security documents.

21. A method according to any of the preceding claims, wherein the first, second and/or third regions define respective indicia such as a character, letter, number, symbol, graphic element or the like, the respective indicia preferably
5 being different.

22. A method according to any of the preceding claims, wherein the first and second regions, and hence the third region, are the same such that the reflection enhancing material is retained across the whole of the region in which the
10 curable material is present.

23. A method according to any of claims 1 to 21, wherein the third region is contained within the first region, such that the reflection enhancing material is retained across less than the whole of the region in which the curable material is
15 present.

24. A method according to any of the preceding claims, wherein the substrate comprises any of: polypropylene (PP), orientated polypropylene (OPP), biaxially orientated polypropylene (BOPP), polyethylene terephthalate (PET),
20 polyethylene, polyamide, polycarbonate, or polyethylene naphthalate (PEN).

25. A method according to any of the preceding claims, wherein the security document is a banknote, a polymer banknote, a hybrid paper/polymer banknote, an identity document, a passport, an identification card, a cheque, a visa, a
25 certificate, or a stamp.

26. A security document manufactured in accordance with any of claims 1 to 25, wherein the security document is preferably a banknote, a polymer banknote, a hybrid paper/polymer banknote, an identity document, a passport,
30 an identification card, a cheque, a visa, a certificate, or a stamp.

27. A security document, comprising:
a polymeric substrate having first and second surfaces;

a cured material disposed in a first region of the substrate on its first surface, the cured material having an optically variable effect generating relief structure formed in its surface distal from the substrate;

5 a reflection enhancing material disposed on at least part of the cured material, the reflection enhancing material following the contours of the relief structure, wherein the reflection enhancing material is a metal or alloy, or a high refractive index (HRI) material; and

10 one or more coating layers disposed on the first and/or second surface(s) of the substrate, the coating layer(s) being absent on at least one of the first or second surfaces across all or part of the first region to define a viewing region;

wherein the cured material, the reflection enhancing material and the viewing region defined by the one or more coating layers are registered to one another.

15 28. A security document according to claim 27, manufactured in accordance with the method of any of claims 1 to 25.

20 29. A security document according to claim 27 or 28, wherein the security document is preferably a banknote, a polymer banknote, a hybrid paper/polymer banknote, an identity document, a passport, an identification card, a cheque, a visa, a certificate, or a stamp.

25 30. A plurality of security documents each according to any of claims 27 to claim 29, wherein the cured material, reflection enhancing material and the viewing region defined by the one or more coating layers have substantially the same positions relative to one another in each of the plurality of security documents.

Fig. 1

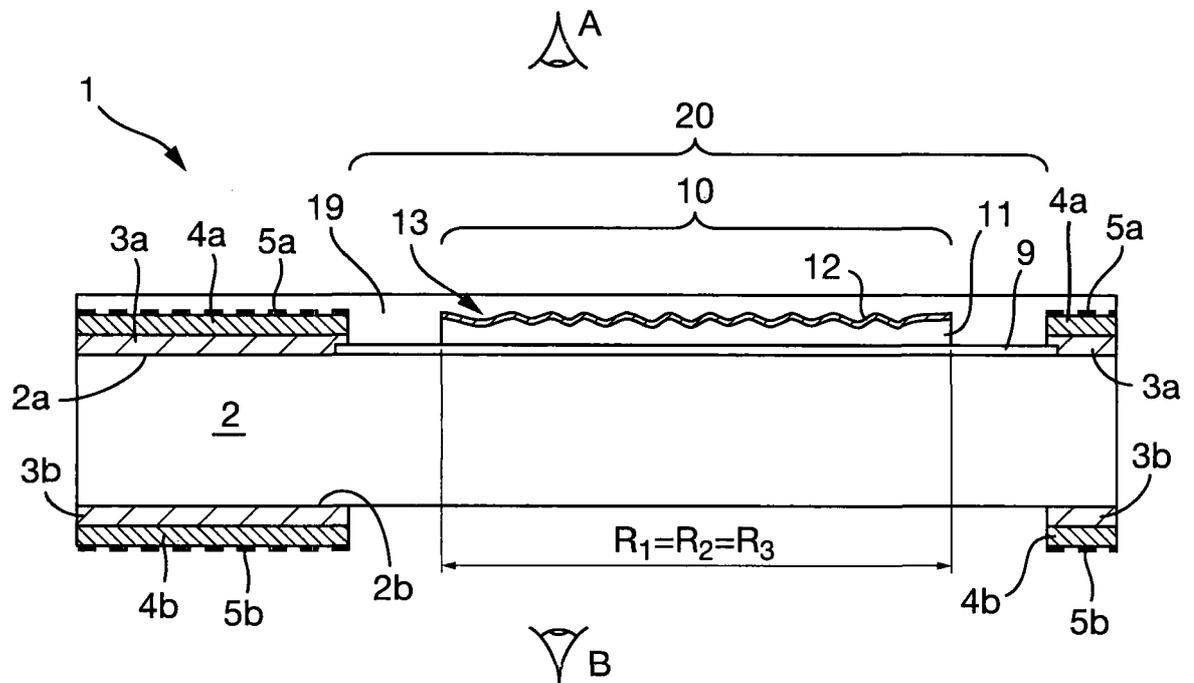


Fig. 2

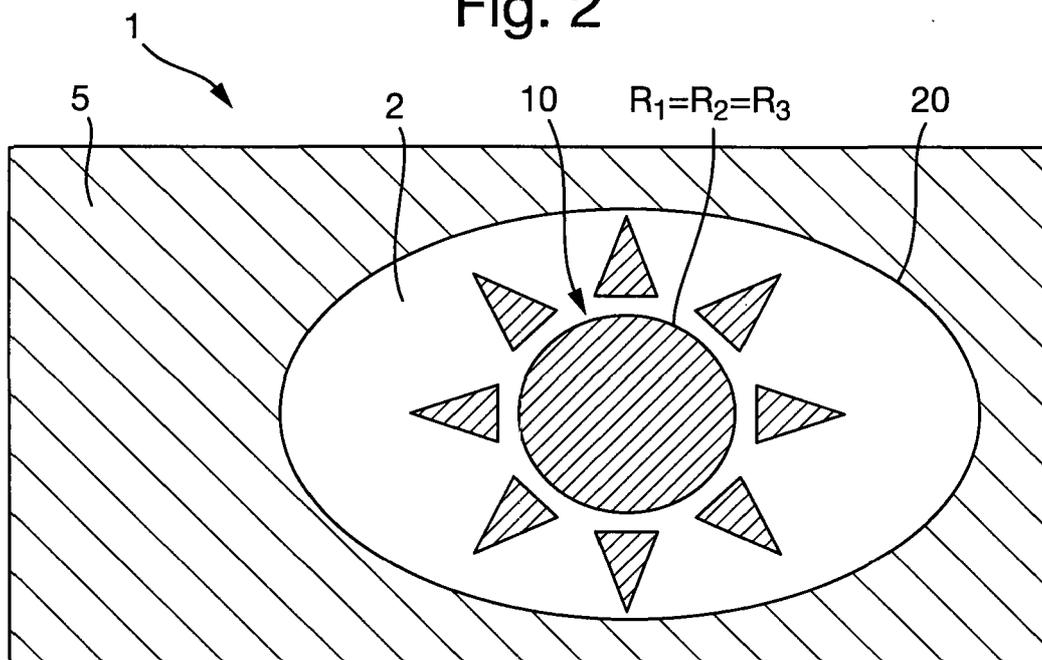
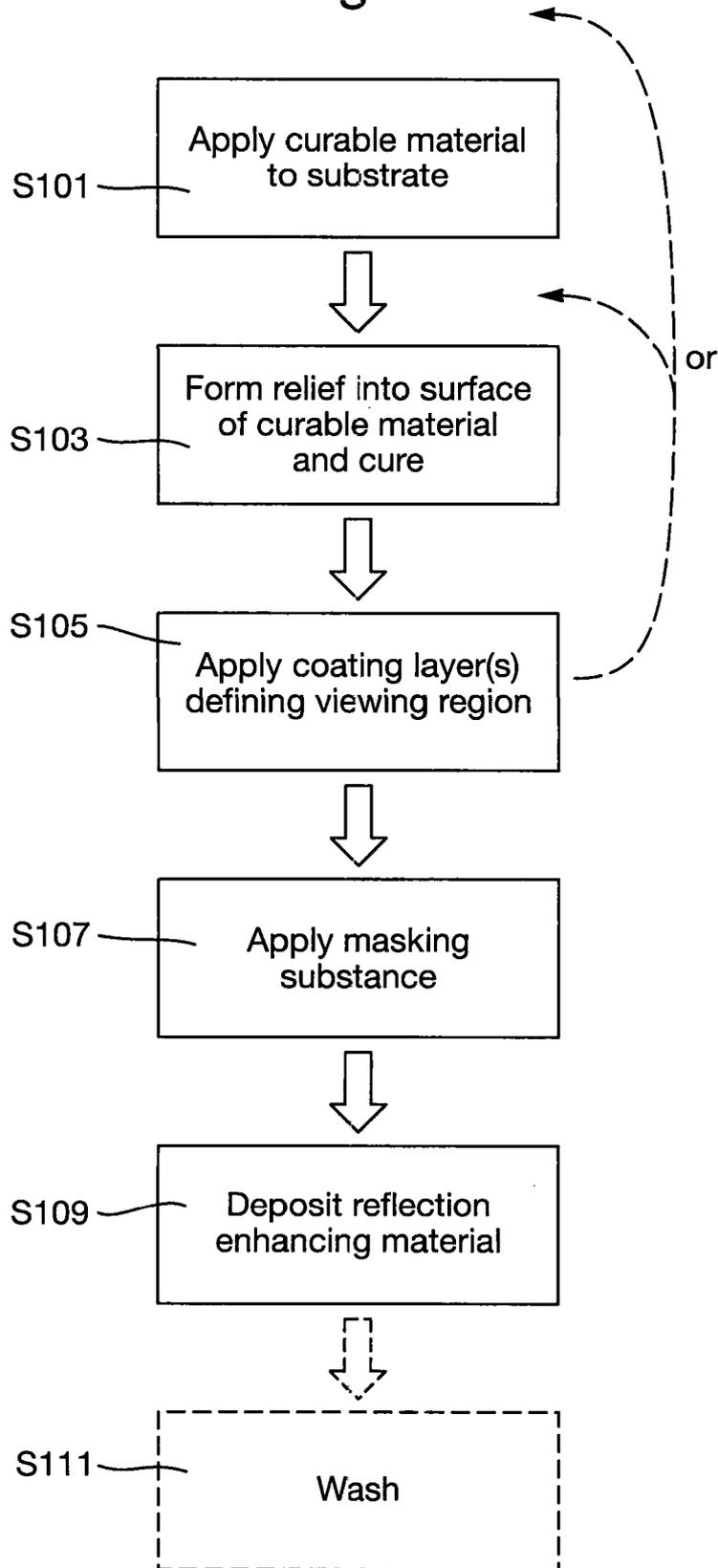


Fig. 3



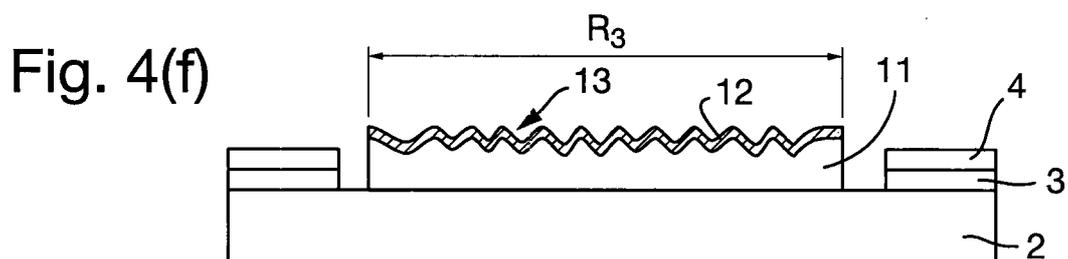
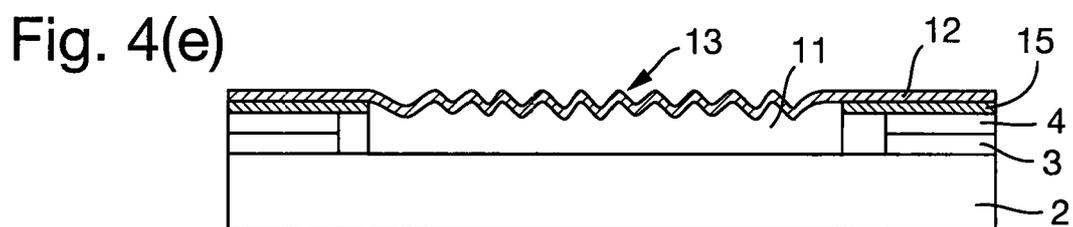
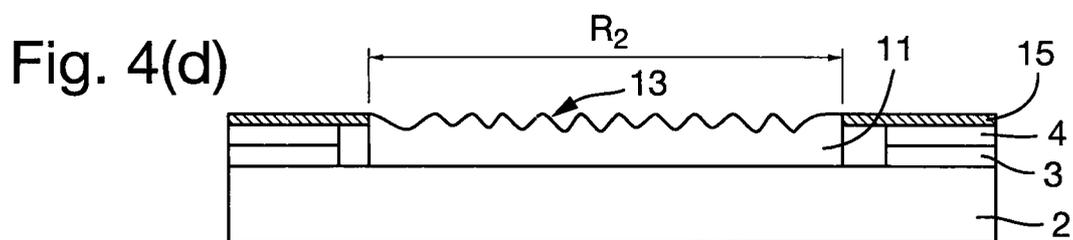
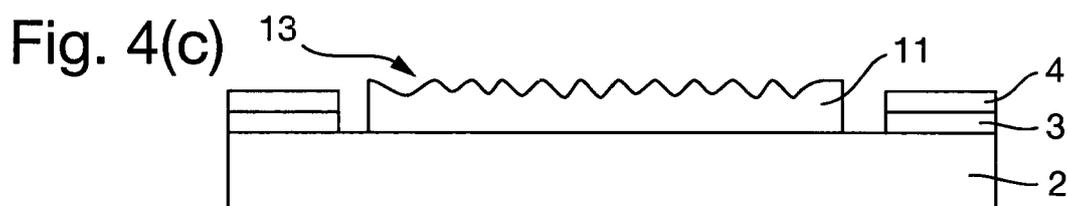
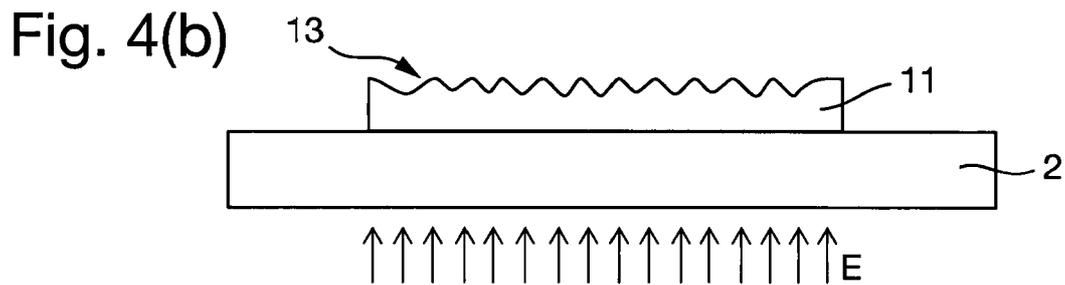
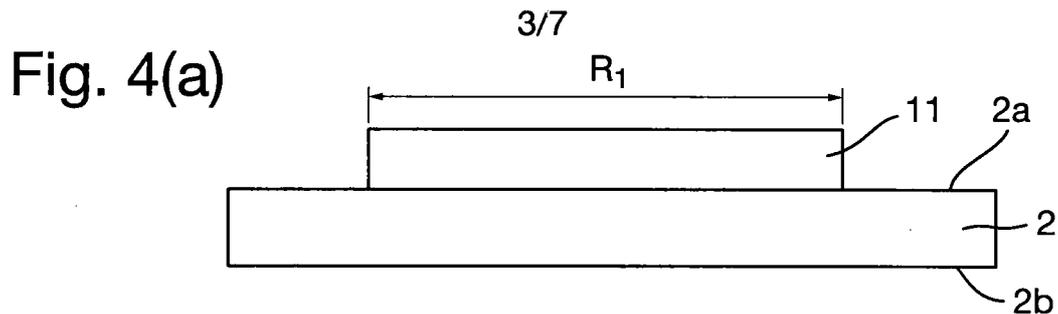


Fig. 5(a)

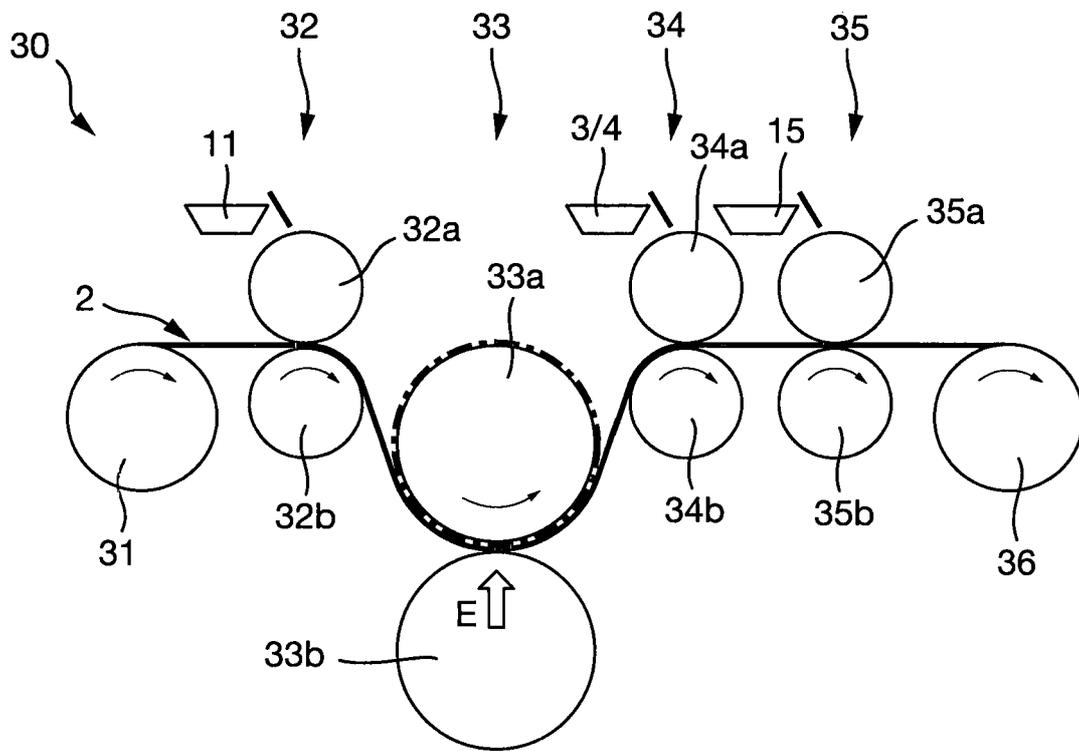


Fig. 5(b)

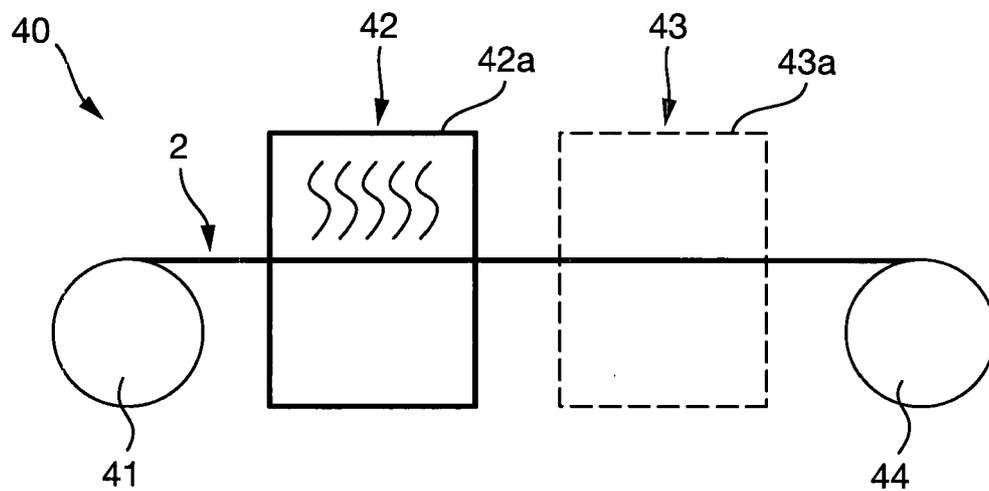


Fig. 6

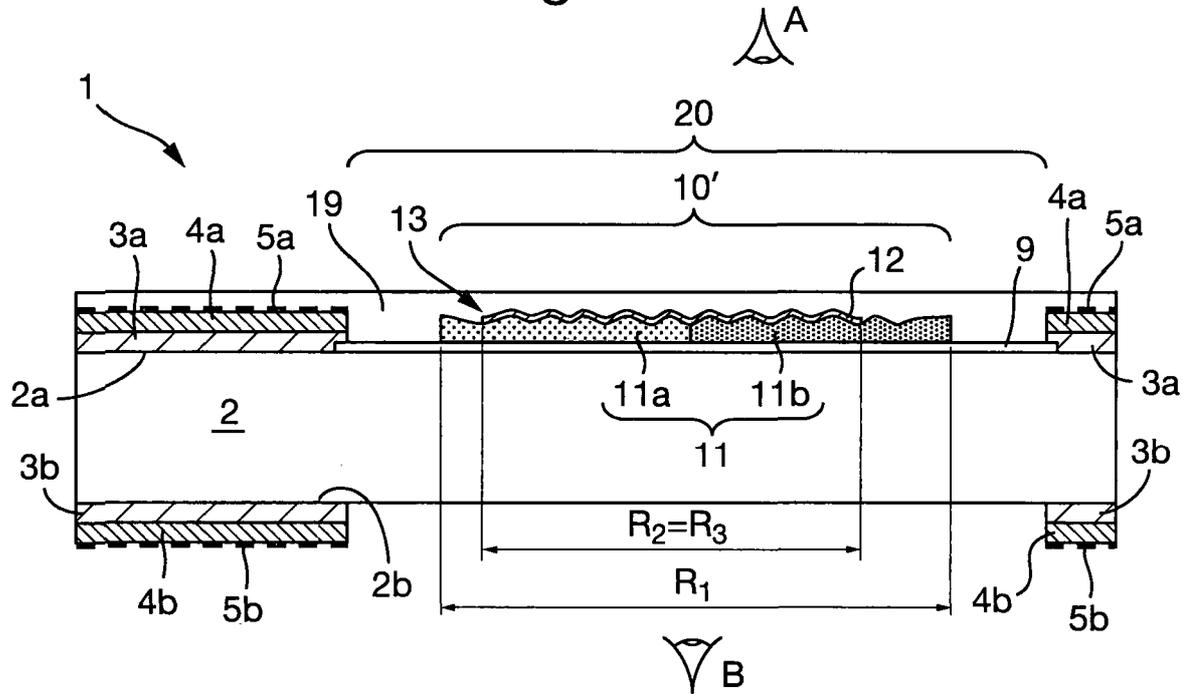


Fig. 7

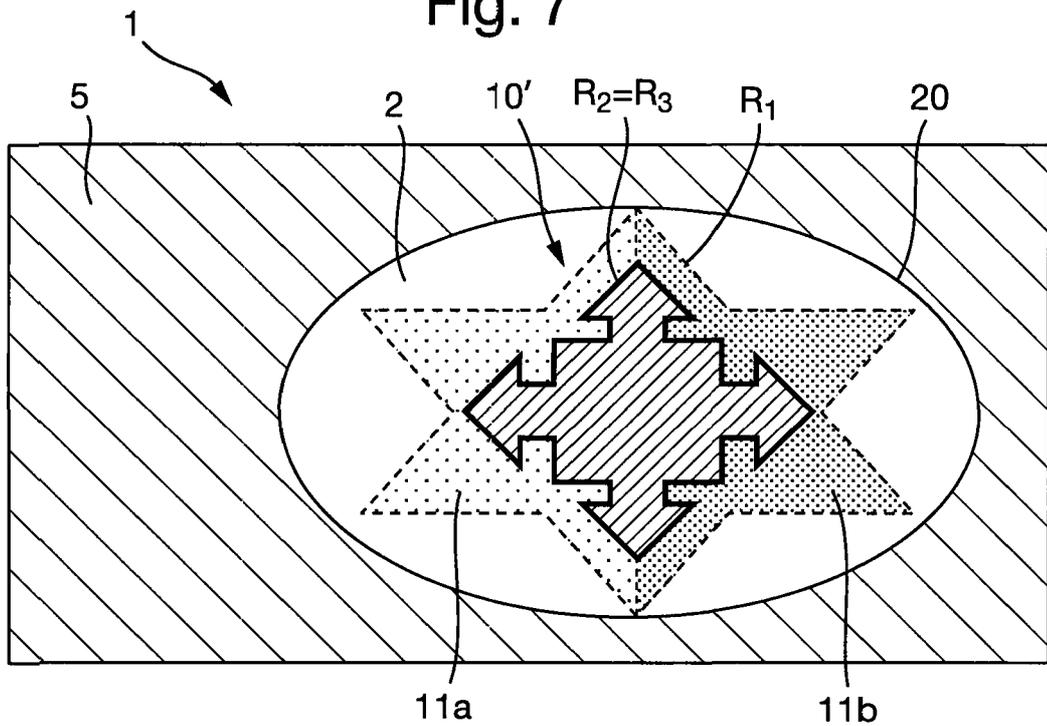
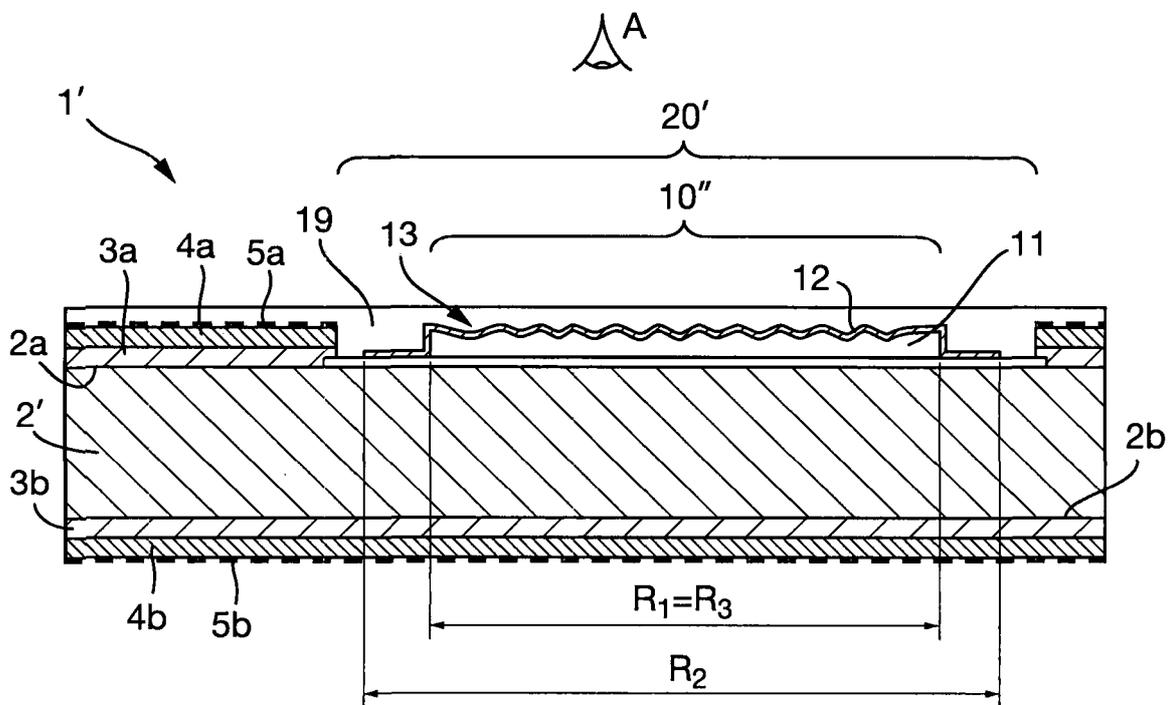


Fig. 8



INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2014/051486

A. CLASSIFICATION OF SUBJECT MATTER
INV. B42D25/328
ADD. B42D25/351

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)
B42D G03H G02B

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 practicable, search terms used)

EPO-Internal , WPI Data

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Further documents are listed in the continuation of Box C.



See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search

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Date of mailing of the international search report

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INTERNATIONAL SEARCH REPORT

International application No

PCT/GB2014/051486

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
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