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(71) Applicant: **DE LA RUE INTERNATIONAL LIMITED**
[GB/GB]; De La Rue House, Viables, Basingstoke Hampshire RG22 4BS (GB).

(72) Inventor: **LISTER, Adam**; 62 Watermills Close, Andover Hampshire SP10 2ND (GB).

(74) Agent: **GILL JENNINGS & EVERY LLP**; The Broadgate Tower, 20 Primrose Street, London Greater London EC2A 2ES (GB).

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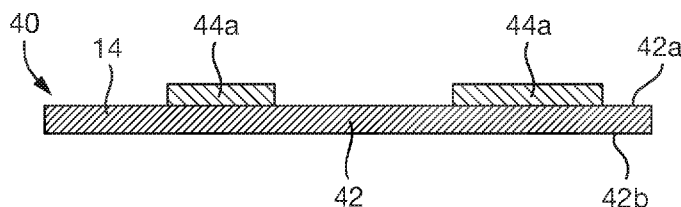
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Fig. 4



(57) Abstract: There is provided a method of manufacturing a security device, comprising the steps of: providing a transfer assembly comprising a carrier layer and a liquid crystal layer carried by the carrier layer; bringing the liquid crystal layer into contact with a first side of a substrate assembly, the substrate assembly comprising a substrate; heating a first pattern of the liquid crystal layer such that regions of the liquid crystal layer corresponding to the first pattern are fixed to the substrate assembly; and separating the unheated regions of liquid crystal material from the substrate assembly; wherein the remaining regions of the liquid crystal layer fixed to the substrate assembly are birefringent or are made birefringent subsequent to the fixing step.



SECURITY DEVICES AND METHODS OF MANUFACTURE THEREFOR

FIELD

- 5 Embodiments of the present invention relate generally to improved methods of manufacturing security devices, security articles and security documents, and the corresponding products produced using these methods.

BACKGROUND

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Articles of value, and particularly documents of value such as banknotes, cheques, passports, identity cards, driver's licences, credit cards, certificates of authenticity, fiscal stamps and the like are frequently the target of counterfeiters and persons wishing to make fraudulent copies thereof and/or changes to any
15 data contained therein.

Typically such objects and documents are provided with security devices to confirm the authenticity of the object.

20

In particular, documents of value are commonly provided with visible security devices which allow the holder to immediately assess the veracity of the document. Examples of such security devices include complex printed patterns, security inks and structural features, such as holograms, lenticular devices and moiré interference devices. Other known security devices include, watermarks,
25 embossings, perforations and the use of iridescent (e.g. colour-shifting) or luminescent / fluorescent inks. The visual effects exhibited by such devices are extremely difficult, or impossible, to copy using traditional reproduction techniques such as photocopying.

30

Equally, objects and documents may also be provided with covert security devices which exhibit effects that are not visible to the naked eye under natural light. These devices may include magnetic materials or luminescent and fluorescent inks which are only visible under certain conditions (e.g. under infrared or UV light).

Nevertheless, there is a constant need to develop new security devices with more complex overt and covert effects in order to stay ahead of would-be counterfeiters.

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Furthermore, as security devices have become increasingly complex, the methods required to produce security devices and security documents have also increased in complexity. Consequently, known methods of producing security devices and security documents are slow, expensive and require large and complicated machinery. Hence, there is a need for security devices which may be manufactured quickly, easily and accurately.

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In summary, there is a pressing need for complex security devices, security articles and security documents which may be quickly and efficiently manufactured.

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SUMMARY OF INVENTION

According to an aspect of the invention, there is provided a method of manufacturing a security device, comprising the steps of:

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providing a transfer assembly comprising a carrier layer and a liquid crystal layer carried by the carrier layer;

bringing the liquid crystal layer into contact with a first side of a substrate assembly, the substrate assembly comprising a substrate;

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heating a first pattern of the liquid crystal layer such that the regions of the liquid crystal layer corresponding to the first pattern detach from the carrier layer and are fixed to the substrate assembly;

and

30

separating the unheated regions of liquid crystal material from the substrate assembly;

wherein the remaining regions of the liquid crystal layer fixed to the substrate assembly are birefringent or are made birefringent subsequent to the fixing step.

Advantageously, this thermal transfer method allows for the quick, simple and efficient creation of covert, personalised security devices, which are not easily reproduced or tampered with by would-be counterfeiters. In particular, the method is more accurate, quicker, requires less machinery and results in less waste than alternative methods of digitally printing or applying liquid crystal to a substrate used in the production of security devices such as the laser ablation of liquid crystal layers.

The birefringent regions of liquid crystal in security devices manufactured according to the above method cannot be readily distinguished from the surrounding regions of the security device under unpolarised light, such as sunlight or natural light and light from traditional incandescent light bulbs – i.e. the security device is covert. However, the liquid crystal regions strongly contrast with (i.e. visually stand out against) regions of the security device which are not provided with birefringent material when the security device is seen through a linear polariser under linearly polarised light.

Furthermore, the visual or optical appearance of the security device will vary as the polariser is rotated relative to the path of light emitted from the polarised light source (i.e. the direction of transmission through the polariser). Specifically, as either the incident light is rotated or the polariser is rotated the regions of the security device with liquid crystal will become relatively darker or lighter in comparison to the regions of the security device without liquid crystal.

It is very difficult to imitate or copy this visual effect using conventional reproduction means (e.g. photocopiers, conventional ink printers). Equally, it is difficult to modify or tamper with security devices manufactured to the method described above.

Control of the pattern of heat applied to the liquid crystal can be used to create “personalised” security devices. A personalised security device may have a different visual appearance to the preceding and subsequent security devices manufactured by a system. For instance, the visual appearance of the security device under polarised light may be linked to the bearer of the security device or

a document or article on which the security device is located. The use of such complex personalised security devices makes it increasingly difficult for would-be counterfeiters to imitate the security device.

5 A further advantage of the present invention is that the liquid crystal material may be suitably formed, aligned and cured before it is transferred to the substrate assembly. This avoids the need to perform additional alignment or curing steps after the liquid crystal is transferred to the substrate assembly, and may avoid the need to provide any additional alignment or primer layers to the
10 substrate assembly (thereby reducing the number of components which are present in the final security device). This is especially beneficial when the liquid crystal material is applied to or in contact with a layer or component of the substrate assembly (e.g. a polariser layer) which is not well suited to be used as an alignment layer.

15

Throughout this specification, the term "light" refers to both visible light (see below) and non-visible light outside the visible spectrum, such as infra-red and ultraviolet radiation. "Visible light" refers to light having a wavelength with the visible spectrum, which is approximately 400 to 750nm. It is most preferable that
20 the visible light is white light, i.e. comprises substantially all the visible wavelengths in approximately equal proportions. The ultra-violet spectrum typically comprises wavelengths from about 200nm to 400nm, and the infra-red spectrum typically comprises wavelengths from about 750nm to 1mm.

25 Many light sources emit light which is incoherent or "unpolarised". This unpolarised light typically comprises electromagnetic radiation which oscillates randomly, i.e. in substantially all transverse directions in more or less even proportions. Light sources which emit unpolarised light include the sun, incandescent lamps and other thermal (black body) emitters, and fluorescent
30 lamps. In comparison, "polarised light" is electromagnetic radiation where the electromagnetic radiation oscillates in substantially a single direction or plane.

For instance, the covert visual effects discussed herein may be observed under linearly polarised light generated from unpolarised light using a linear polariser.

Polarisers (also known as polarising filters) are optical filters which allow light waves of a specific polarisation pass through them and block light waves of other polarisations. Linear polarisers allow light of a single linear polarisation (i.e. light which vibrates in a single primary axis) to pass through. Common types of linear polarisers include absorptive polarisers, which absorb light waves of substantially all polarisations except the polarisation which is transmitted through the polariser, beam-splitting polarisers which split unpolarised light into two beams of opposite polarisations and reflective polarisers which reflect all light except light vibrating in a single axis. Common emitters of linearly polarised light include LCD screens such as those used in televisions, computer monitors and mobile (cellular) telephones.

In contrast, the covert visual appearance will not be seen under circularly polarised light (where the electric field of the light rotates as the light propagates). In other words, the devices described in this document will look similar under unpolarised and circularly polarised light but exhibit a covert visual effect under linearly polarised light. Circularly polarised light may be obtained by passing linearly polarised light through a quarter-wave plate, and from unpolarised light using a "circular polariser" which comprises a linear polariser and a quarter-wave plate in sequence.

Throughout this specification it is understood that the term "side" refers to an exterior surface of a material, and in the case of a layer is generally used to refer to an exterior surface which extends substantially parallel to the plane in which the layer extends.

"Birefringent" materials are optically anisotropic, exhibiting different refractive indexes depending on the polarisation and direction that light propagates through the material. Consequently, light travels at a different speed in one direction through these materials than in another.

As light passes through a birefringent material different components of the light (in accordance with the axes of the material which have different refractive indices) will travel at different speeds through the birefringent material.

Consequently, the different components of the light will fall out of phase with one another as they travel through the birefringent material.

When the light exits the birefringent material the two components of the light
5 recombine. Consequently, the direction of polarisation of the light transmitted through the birefringent material will be turned or rotated due to the phase difference between the components of the light.

Under unpolarised white light in which light vibrates randomly in substantially all
10 directions no change is observed. However, polarised light exits a birefringent material with a different polarisation in comparison to the light which entered (i.e. was incident to) the birefringent material.

The degree by which the polarisation of polarised light is rotated by a birefringent
15 material is affected by both the geometry of the material (e.g. the thickness of the material) and its optical properties (e.g. the relative difference between the refractive indices for light propagating in different directions or of different polarisations). Consequently, the visual effects exhibited by security devices manufactured according to the method outlined above may be adjusted by
20 careful selection of the geometry and optical properties of the liquid crystal layer.

The substrate assembly preferably comprises at least a substrate adapted to carry the regions of liquid crystal (i.e. wherein the regions of liquid crystal material are in contact or above a side of the substrate). This substrate may
25 perform further functions e.g. it may be a polariser or carry traditional print workings. The substrate may be of multi-layer construction or a single unitary layer. Equally, the carrier layer is adapted to carry the liquid crystal layer, such that the liquid crystal layer is provided in contact or above a side of the carrier layer. The carrier layer may be of multi-layer construction or a single unitary
30 layer.

Preferably, the substrate or the carrier layer comprise a plastic material, such as: polyethylene terephthalate (PET), biaxially orientated polypropylene (BOPP), polycarbonate (PC), polyvinylchloride (PVC), polybutylene terephthalate (PBT),

nylon or acrylic. The benefits of plastics or polymers are that they are durable, waterproof, strong, tear resistant, and easily recyclable. In other embodiments, the substrate or the carrier layer may be formed of alternative materials such as resin, paper or glass. For instance, the carrier layer may be formed of Mitsubishi
5 RNK 19 (RTM), a form of polyethylene terephthalate, and the substrate may be formed of BOPP, or vice versa.

Preferably, the step of separating the unheated regions of liquid crystal from the substrate assembly can be performed mechanically – i.e. by removing the
10 transfer assembly from being in contact with the substrate assembly. The heated regions of liquid crystal remain on the substrate assembly and detach from the carrier layer since they have been fixed or secured to the substrate assembly. In contrast, the unheated regions of liquid crystal will remain affixed to the transfer assembly when it is removed. Alternatively, the regions of liquid
15 crystal may be removed or separated from the substrate assembly chemically by dissolving or eroding the unheated regions of liquid crystal, or by ablating the unheated regions of the liquid crystal layer.

In some embodiments of the invention the liquid crystals layer may comprise
20 liquid crystals in a nematic phase. Advantageously, liquid crystals in the nematic phase are easily aligned to create the desired birefringence, exhibit a strong visual effect under polarised light, are easy to handle, and when heated readily bond to the substrate assembly and detach from the transfer assembly. Alternatively or additionally, the liquid crystal layer may comprise liquid crystals
25 in other phases (e.g. a smectic phase).

Suitable liquid crystal materials include 4-Cyano-4'-pentylbiphenyl and 4'-Hydroxy-4-biphenylcarbonitrile which are both nematic liquid crystals. Preferably the liquid crystal layer is as thin as possible to reduce the overall thickness of the
30 transfer assembly and final security device. In preferred embodiments the liquid crystal layer is provided to the transfer assembly in a layer with a density of less than 2 g/m^2 , more preferably the liquid crystal layer has a density of less than 1 g/m^2 , more preferably still the liquid crystal layer has a density of approximately 0.5 g/m^2 or less.

In particularly preferred embodiments, a transfer assembly is initially provided that comprises carrier layer which carries a birefringent liquid crystal layer – e.g. the carrier layer carries a cured liquid crystal layer in which the liquid crystal
5 molecules are aligned such that the layer is birefringent. This simplifies the process of manufacturing security devices as no separate alignment or curing steps are required.

Alternatively the method may comprise the further step of aligning the liquid
10 crystal layer or the regions of the liquid crystal layer fixed to the substrate assembly, such that the respective liquid crystal layer or regions are birefringent.

The “alignment” of a liquid crystal layer it is understood to refer to the ordering and arrangement of the individual molecules of liquid crystal is changed within
15 the layer (i.e. on a micro-scale). A change in alignment of molecules within the layer will affect the optical properties of the liquid crystal as a whole (i.e. on a macro-scale) and may be used to create a birefringent effect.

To create a macroscopic birefringent effect a significant proportion of the
20 molecules within the liquid crystal layer may be aligned to one another such that the layer as a whole is optically anisotropic. Preferably the majority or substantially all of the molecules are aligned, such that the macroscopic properties of the layer (e.g. optical, mechanical and electrical properties) are consistent throughout the layer. Advantageously, a liquid crystal layer in which
25 there is substantially unidirectional alignment of the molecules exhibits a strong or vivid birefringent effects when seen under polarised light and through a polariser.

For example, in a nematic phase liquid crystal molecules may be aligned such
30 that long axes of the molecules are roughly parallel (i.e. the molecules have long-range directional order), whilst in a smectic phase the liquid crystal molecules may orientated in layers of molecules. In each case the molecules may be orientated such that a substantial proportion of the crystals are aligned

either parallel (homogeneous alignment) or perpendicular (homoeotropic alignment) to the plane of the liquid crystal layer.

5 Preferably the step of aligning the liquid crystal layer or the regions of the liquid crystal layer fixed to the substrate assembly is performed using an alignment layer placed in contact with the liquid crystal layer.

10 In particularly preferred embodiments, the transfer assembly comprises an alignment layer positioned between the carrier layer and the liquid crystal layer, the alignment layer being adapted to align liquid crystals within the liquid crystal layer such that the liquid crystal layer is birefringent. Consequently, the liquid crystal layer will be aligned and birefringent during the manufacture of a security device when it is provided to the transfer assembly and is in contact with or adjacent to the alignment layer. As discussed below, the liquid crystal material
15 may then be cured to permanently fix or retain its alignment at substantially any point whilst it is in contact or adjacent to the alignment layer. Advantageously, this avoids the need to provide a separate, external alignment layer or perform an additional alignment step and thus simplifies the manufacturing process.

20 Alternatively, an alignment layer may be provided at the exterior surface of the substrate. For instance, an alignment layer may be provided in contact with or above the first side of the substrate (i.e. such that it is carried by or on the substrate), the substrate may be formed of an appropriate material such that it acts as an alignment layer, or a multi-layer substrate may comprise an alignment
25 sub-layer. Therefore, when the transfer assembly is brought together with the substrate assembly the liquid crystal layer is brought into contact with the alignment layer and is aligned.

30 In this case the alignment (i.e. the internal structure) of the regions of the liquid crystal layer transferred to the substrate assembly is fixed or secured because the liquid crystal layer is not easily removed from the underlying alignment layer. Hence, it is difficult to modify or tamper with the visual effect of the security device since the effect is governed by the underlying alignment layer.

In particularly preferred examples the alignment layer comprises a polyvinyl alcohol (PVA or PVOH) or a polyimide (PI). For instance, the alignment layer may be formed of Poval L (RTM) which is a polyvinyl alcohols containing 3% CaCO₃ produced by Kuraray (RTM). Alternatively, the alignment layer may
5 comprise Elvanol (RTM), a polyvinyl alcohol produced by Kuraray (RTM). Elvanol (RTM) which can simultaneously perform the functions of an alignment layer and a primer layer.

Advantageously, these layers provide simple, quick and cost effective means of
10 aligning liquid crystal layers and are therefore well suited to be used in the manufacture of a security device. Alternatively any other suitable material(s) may be used. For instance, an appropriate alignment layer may comprise a regular surface relief which causes adjacent liquid crystals in a liquid crystal layer to be aligned to the surface relief.

15

In further alternative embodiments an alignment layer may not be necessary. For instance, the liquid crystal layers (and the molecules within these layers) may instead be aligned by the application of an electric or magnetic field to the layer, or by mechanically rubbing a polymer layer with a cloth or a brush and
20 placing this polymer layer in contact with the liquid crystal material.

Equally, in other embodiments the liquid crystal layer may only be aligned after manufacture or whilst the security device is in use (e.g. after a device has been issued). For instance, the liquid crystal layer may be temporarily or permanently
25 aligned by applying an electromagnetic field or by providing an alignment layer in contact with the liquid crystal layer to the security device after all previous manufacturing steps have concluded, e.g. when the security device is in use.

The method may comprise the further step of curing the liquid crystal layer or the
30 regions of the liquid crystal layer fixed to the substrate using ultraviolet radiation to fix the internal structure of the respective liquid crystal layer or regions. Any suitable ultraviolet light source may be used for this step. For instance, the liquid crystal may be cured using a 1 second exposure to ultraviolet light emitted by a mercury arc lamp with a power rating of 120 W/cm.

Curing a liquid crystal layer creates cross-links between adjacent liquid crystal molecules, securing the alignment and optical properties of the liquid crystal. This may require the presence of suitable polymerisable groups (e.g. acrylate groups) in the liquid crystal molecules within the liquid crystal layer. Appropriate liquid crystal materials are manufactured by Merck (RTM). Curing the liquid crystal material is beneficial as the permanent internal structure of a cured liquid crystal layer is difficult to modify or tamper with. Furthermore, the liquid crystal material will retain its optical properties (e.g. birefringence) even if the material is brought into contact with or removed from being in contact with an alignment layer, or if there are changes to the electrical and magnetic fields applied to the liquid crystal material.

This curing step may be performed at substantially any stage of the method whilst the uncured liquid crystal is birefringent. For instance, where an alignment layer is provided as part of the transfer assembly as discussed above the liquid crystal may be cured at any point before the transfer assembly and the substrate assembly are separated from one another and the liquid crystal is removed from contact with the alignment layer.

As discussed above, according to the first aspect of the invention regions of the liquid crystal layer which are heated and transfer or fix to the substrate assembly and detach from the transfer assembly. This transfer is governed by the relative strengths of: the cohesive forces between the unheated and heated regions of the liquid crystal layer; the adhesive forces between the liquid crystal layer and the carrier layer of the transfer assembly; and the adhesive forces between the liquid crystal layer and the substrate assembly.

Preferably, under normal conditions (room temperature between 0 and 25 degrees Celsius and pressure of 100 kPa) the combined action of the cohesive forces holding the liquid crystal layer together and the adhesive forces between the liquid crystal material and the carrier layer is greater than the adhesive forces between the liquid crystal layer and the substrate assembly. The liquid

crystal layer therefore remains part of the transfer assembly even when brought into contact with the substrate assembly at normal temperatures.

5 Whereas, when the liquid crystal is heated the adhesive forces between the liquid crystal material and the substrate become greater than the combined action of the cohesive forces between the heated and unheated regions of the liquid crystal layer and the adhesive forces between the liquid crystal layer and the carrier layer. Consequently, when the carrier layer and substrate assembly are separated the heated regions of the liquid crystal layer will detach or
10 separate from the carrier layer and from adjacent unheated regions of the liquid crystal layer and will adhere to the substrate or another adjacent component of the substrate assembly.

15 Preferably the transfer of heated regions of the liquid crystal layer involves a clean separation of the heated liquid crystal regions from the carrier layer and the adjacent unheated regions of liquid crystal without any residue remaining on the carrier layer. This ensures a strong contrast between the heated regions of liquid crystal transferred to the substrate assembly and the surrounding regions of the security device and creates a strong visual effect.

20 In certain preferred embodiments, the cohesive forces between the liquid crystal layer and the transfer assembly, and the cohesive forces between the liquid crystal layer and the substrate assembly are regulated using a primer layer and a receiving layer respectively.

25 In preferred embodiments the transfer assembly further comprises a primer or release layer positioned between the carrier layer and the liquid crystal layer, the primer layer being adapted to regulate the adhesive force between the liquid crystal layer and the remaining portions of the transfer assembly. Alternatively,
30 a primer material may be formed as an exterior sub-layer at the exterior surface multi-layer carrier layer.

The primer layer may comprise a polyester resin or a vinyl resin. Equally, any other suitable material(s) may be used as a primer layer to regulate the adhesive

force between the liquid crystal layer and the remaining portion of the transfer assembly.

As discussed above, in particularly preferred embodiments the carrier layer
5 comprises a combined alignment and primer layer, the alignment and primer
layer being adapted to align liquid crystals within the liquid crystal layer such that
the liquid crystal layer is birefringent and to regulate the adhesive force between
the liquid crystal layer and the carrier layer. This single combined layer performs
the functions and comprises the features of the alignment and primer layer
10 discussed above. For instance, Elvanol (RTM), a polyvinyl alcohol produced by
Kuraray (RTM) is particularly preferred as it may simultaneously act as a primer
layer and an alignment layer.

In addition, or as an alternative, the substrate may be provided with a receiving
15 layer positioned in contact with or above its first side, the receiving layer being
adapted to enhance the adhesive force between the substrate and the liquid
crystal. For instance, the receiving layer may be formed as an exterior sub-layer
on the first side of a multi-layer substrate or a separate layer applied to the first
side of the substrate.

20 For instance, the receiving layer may comprise polyvinylpyrrolidone (PVP) or
polyvinyl butyral (PVB). Equally, any other suitable material(s) may be used as
a receiving layer to regulate the adhesive force between the liquid crystal layer
and the substrate.

25 Alternatively, the adhesive forces between the liquid crystal layer and the
underlying components of the transfer assembly may be regulated by varying
the surface roughness of the layer of the transfer assembly in contact with the
liquid crystal layer, or by forming microstructures in the surface of this underlying
30 component. Therefore, the method may include the initial step of forming or
generating the surface roughness or the microstructures. However, this step is
not essential.

Equally, in exemplary embodiments the method may include a step of applying surface roughness or a microstructure to a side of the substrate, or a layer (e.g. a polariser layer) of the substrate assembly carried by the substrate (i.e. applied in contact with or above a side of the substrate) to which the liquid crystal will be applied. Again, this may be used to regulate the adhesive forces between the liquid crystal and these components. This step is not essential.

For instance, the surface roughness of the transfer or substrate assembly may be modified by applying a 'reverse gravure' printing process to either the transfer or substrate assembly. In this process a web of the assembly to be modified may be passed between a roughened gravure cylinder and an impression roller, wherein the roughened gravure cylinder rotates in the opposite (i.e. reverse) direction to the direction of travel of the web and impart its roughness to the web.

In particularly preferred embodiments the substrate assembly comprises a polariser configured to prevent incident visible light waves of a predetermined polarisation passing through the polariser. For instance, the substrate may be formed of a polariser. Alternatively, a polariser may be provided as a sub-layer within a multi-layer substrate. Equally, or additionally the method may include the further step of providing a polariser in contact with or above a side of the substrate i.e. such that the polariser is carried by the substrate and forms part of the final security device. This step may be performed before, after, or simultaneously with the other methods steps discussed above.

In each of the examples discussed above the polariser is integral to (i.e. comprised within) the security device. Security devices comprising an integral polariser are particularly preferred as the birefringent effect generated by the regions of the liquid crystal layer transferred to the substrate is visible under polarised light. Advantageously there is no requirement to provide an additional, separate polariser to view the effect. This is particularly beneficial as the covert effect may be simply seen under light emitted from, for instance, the LCD screen of a mobile (cellular) telephone, TV or computer monitor.

However, since the covert visual effect exhibited by the birefringent material is only seen under polarised light and through a polariser, in these embodiments the visual effect will only be observed from a single side of a security device. Specifically, the effect will only be observed if the security device is orientated
5 such that the liquid crystal material is located between the polarised light source and the liquid crystal. As a corollary, the covert visual effect will only be observed in transmitted light when the security device is positioned such that the polariser is located between the liquid crystal material and an observer.

10 In alternative examples the security devices discussed herein may be manufactured without a polariser configured to prevent incident visible light waves of a predetermined polarisation passing through said polariser within the substrate assembly. In other words, security devices with a pattern of birefringent liquid crystal material do not necessarily require an integral polariser.

15 It will be appreciated that in these examples the covert, personalised visual effects discussed above will still be observed under polarised light when a security device without an integral polariser is viewed through a separate, independent polariser.

20 Security devices without integral polarisers offer equivalent benefits to the security devices with polarisers comprised within the substrate assembly discussed above. These benefits include improved security as the covert visual effect seen under polarised light through a separate polariser cannot be easily imitated, modified or tampered with.

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Furthermore, it will be appreciated that no modifications must be made to either the remaining steps of the methods discussed herein, or the other features of security devices manufactured to these methods, in order to compensate for the absence of a polariser within the substrate assembly.

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Preferably the polariser prevents at least 50% of incident visible light waves of a predetermined polarisation from passing through the polariser, more preferably the polariser prevents at least 75% of incident visible light waves of a predetermined polarisation from passing through the polariser, more preferably

still the polariser prevents at least 90% of incident visible light waves of a predetermined polarisation from passing through the polariser. The visual effect seen under polarised light becomes stronger and is more readily observed as the proportion of light blocked by the polariser increases. In preferred
5 embodiments the polariser is a linear polariser arranged to permit light of a single linear polarisation to pass through.

The polariser is preferably a linear polariser and may be an absorptive, beam-splitting or reflective polariser. For instance, 3M (RTM) produce a variety of
10 giant birefringent optical (GBO) films which are suitable for use as polarisers in the security devices discussed herein. Furthermore, 3M (RTM) produce a variety of suitable linear polarisers under the Vikuiti (RTM) brand. Advantageously, these Vikuiti polarisers are flexible and are well suited for use in security documents being resistant to damage and are appropriate for a wide range of
15 manufacturing techniques. Equally, alternative linear polarisers such as an iodine doped stretched PVOH film or a wire-grid polariser may be used.

Alternatively, circular polarisers (which comprise a linear polariser and a quarter wave plate in sequence) may also be used. To an observer security devices
20 comprising circular polarisers will appear substantially the same as security devices which comprise only linear polarisers. This is because in each case light transmitted through a security device will reach a linear polariser and be transmitted or blocked (i.e. reflected or absorbed) depending on its polarisation. When the security device comprises a circular polariser the light which exits the
25 linear polariser will subsequently be converted into circularly polarised light by the quarter-wave plate. However, the circularly polarised light which exits the quarter-wave plate is otherwise substantially unaffected and appears unchanged to a human observer. This is because the human eye does not perceive any difference between linearly polarised light a circularly polarised light.

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In particularly preferred embodiments the regions of the liquid crystal layer fixed to the substrate are fixed in contact with or above a window in the substrate. Windows are commonly used in security devices found in polymer security documents such as polymer bank notes, identity cards, passports and the like.

Within this specification, a window is understood to be a substantially visually transparent region of an otherwise opaque security device, security article or security document. This may be formed by a region of substantially transparent material formed within an otherwise opaque substrate, or by a gap or aperture in substantially opaque opacifying layer(s) applied to the surface of an otherwise substantially transparent substrate. Preferably the window is substantially visually transparent and at least translucent to visible light (i.e. light with wavelengths between approximately 400 to 750nm).

Opacifying layers comprises an opaque, translucent or semi-opaque material which absorbs, scatters or reflects incident visible light. In some embodiments multiple translucent or semi-opaque opacifying layers may be applied over one another in order to create a combined layer which is sufficiently or substantially visually opaque. Advantageously, the opacifying layer preferably transmits less than 30% of incident visible light in a single pass, more preferably less than 20%, still preferably less than 10%, most preferably is substantially opaque. Preferably one or more opacifying layers comprise an ink or coating preferably comprising a white or grey pigment (e.g. aluminium). However, in alternative preferred embodiments, one or more opacifying layers comprise a polymeric, non-fibrous, light-scattering material.

Advantageously, the birefringent effect exhibited by the security device under polarising light will be readily seen in transmission through the window. Whereas, other markings or printings applied to regions of the security device outside of the window will be readily seen under reflected light in contrast to any underlying substantially visually opaque substrate or opacifying layer(s).

In particularly preferred embodiments heating the liquid crystal layer is performed using a thermal print head. A thermal print head is able to selectively heat regions of print media (e.g. a combination of the transfer assembly and the substrate, as discussed above) using a plurality of individually controlled heating elements arranged in a single direction.

Advantageously, a thermal print head allows for accurate digital printing and is able to vary the pattern in which it heats. This allows such print heads to quickly and efficiently print personalised regions of liquid crystal, such that the pattern of liquid crystal provided to each security device is different. Furthermore, thermal print heads have few moving parts and are highly reliable. Alternatively any other suitable means of heating the liquid crystal layer may be used, such as an electromagnetic radiation source, e.g. a laser, microwave or an infrared light source.

For instance, conventional thermal printers used for thermal printing and thermal transfer printing such as the Zebra (RTM) 110Xi4 are suitable for use in the methods described above. Good transfer of liquid crystal material from transfer assemblies to substrate assemblies has been achieved using the Zebra (RTM) 110Xi4 thermal printer using the standard settings for thermal transfer printing of colour images. Preferably, the print head temperature reaches at least 250°C and more preferably at least 340°C. Preferably the heat duration (i.e. the length of time heat is applied to the transfer assembly and substrate assembly) is at least 7 milliseconds.

Preferably heating the liquid crystal layer comprises applying heat in the first pattern to the second side of the carrier layer.

Advantageously, heat applied to the second side (the reverse) of the carrier layer is quickly transmitted to the liquid crystal layer through the remaining components of the transfer assembly. This results in quick and efficient transfer of the heat to the liquid crystal. In addition, heating the liquid crystal from the opposing side of the carrier layer reduces the heat which is transmitted to the substrate assembly, avoiding damage to the components and features of the final security device.

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Nevertheless, in alternative embodiments the heat may be applied to the second side of the substrate such that heat is transmitted through the substrate to the liquid crystal layer. In further embodiments heat may be applied to the second

side of the transfer assembly and the second side of the substrate simultaneously.

5 Preferably the method comprises a web-fed process. Web fed processes and systems, which use a continuous substrate running through the machines or presses, are very fast in comparison to sheet fed methods and are therefore particularly suitable for the production of high volumes of security devices and security documents.

10 Additionally, or alternatively, the method may comprise sheet fed processes where sheets of substrate are printed individually before being divided may also be used. Sheet fed processes typically offer higher accuracy than web fed processes, and the equipment used for them may be more easily adapted to produce security devices and documents in a variety of different sizes and
15 formats.

Web fed and sheet fed processes may also be combined within a single manufacturing method. For instance, a continuous substrate may first be printed in a web fed process before it is divided into separate sheets for sheet fed
20 printing. This allows efficient printing of security devices and documents as web can be used for steps which do not require the higher accuracy provided by sheet printing may be quickly, whilst workings which must be highly accurate may be applied using a sheet fed printing process.

25 In preferred embodiments the transfer assembly is a ribbon. Ribbons are continuous lengths of an assembly and are commonly used during web-fed processes. Forming the transfer assembly as a ribbon enables a web-fed manufacturing process which can quickly produce large volumes of security devices and documents, as discussed above. Alternatively, the transfer
30 assembly may be a sheet or formed as individual sheets. These sheets are suited for sheet printing and may allow for printing with high accuracy and high registration between separate workings. Equally a transfer assembly which is provided as a ribbon may subsequently be divided into individual sheets as required.

Preferably the first pattern defines a first item of information comprising any of: indicia, alphanumeric text, a letter or number, a symbol, a portrait, a logo or another graphic. Advantageously this information may be quickly distinguished
5 when viewing the device under polarised light, allowing the authenticity of the security device to be quickly and easily verified by an observer.

Preferably the method comprises the further step of applying a print working in contact with or above the first side or second side of the substrate and wherein
10 the print working defines a second item of information comprising at least one of: indicia, alphanumeric text, a letter or number, a symbol, a portrait, a logo or another graphic. For instance, this print working may be used to provide information regarding the bearer or the issuer of a security device, or may provide information regarding the security device (or an article or document
15 bearing the device). Advantageously this traditional print working and the information it conveys may be quickly distinguished when viewing the device under natural, unpolarised light. Preferably the print working is applied using at least one of gravure, flexographic, lithographic or intaglio printing. Alternatively, substantially any other printing technique may be used.

20 If provided, the first and second items of information (exhibited by the liquid crystal and the print working respectively) could take any desirable form. However, if both are provided preferably they exhibit respective items of information which are the same (i.e. have the same semantic meaning, e.g. both
25 are star symbols, both are the digit "5", or both are portraits of the bearer of a security device, article or document), complementary (i.e. different but together form an item of information such as two portions of an image, e.g. "£" and "5", forming "£5", or "5" and "0" forming "50") or conceptually linked (i.e. different but with an intelligible connection, e.g. a portrait of Queen Elizabeth II and "QEII").

30 In accordance with a further aspect of the invention there is provided a method of manufacturing a plurality of security devices, wherein each security device is manufactured according to the methods discussed above and wherein the first pattern is varied for each of said plurality of security devices.

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By varying the first pattern of liquid crystal regions the visual appearance of each security device is personalised. Advantageously this allows each security device to be individually identified based on the specific first pattern of liquid crystal applied to the device. In particularly preferred embodiments the first pattern
5 contains information or graphics which relates or corresponds to the holder or bearer of the security device or a document containing said security device. Alternatively, all of the security devices or a subset of the security devices may be printed with the same pattern of liquid crystal regions such that they exhibit substantially the same visual appearance under polarised light.

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In accordance with a further aspect of the invention, there is provided a security device manufactured in accordance with any of the methods discussed above.

According to an aspect of the present invention, there is provided a security
15 article comprising a security device manufactured in accordance with any of the methods discussed above and wherein the security article is preferably a security thread, strip, foil, insert, transfer element, label or patch.

In accordance with a further aspect of the present invention, there is provided a
20 security document comprising a security device manufactured in accordance with any of the methods discussed above or a security article according to the preceding aspect of the invention, wherein the security document is preferably a banknote, cheque, passport, identity card, driver's licence, certificate of authenticity, fiscal stamp or other document for securing value or personal
25 identity.

Advantageously, these security devices, security articles and security documents exhibit a personalised, covert effect which is visible under polarised light through the polariser (which may or may not be formed as an integral part
30 of the security devices involved without substantive changes to the remaining features of the security devices, articles and documents). Consequently, these devices, articles and documents exhibit a complex visible effect and are not easily reproduced, modified or tampered with by would-be counterfeiters. Furthermore, these security devices, security articles and security documents

exhibit advantages discussed above in reference to the first aspect of the invention.

According to a further aspect of the present invention, there is provided a
5 transfer assembly suitable for use in any of the methods discussed above.

The unexpected benefits of such a transfer assembly which comprise at least a carrier layer and a liquid crystal layer include that a personalised liquid crystal regions may be printed to a substrate during the manufacture of a covert security
10 device. This process is accurate, quick and cost effective when compared to existing methods of printing which are in general unsuited for the printing of liquid crystal layers.

BRIEF DESCRIPTION OF DRAWINGS

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Examples of methods, security devices, security articles and security documents in accordance with the present invention will now be described with reference to the accompanying drawings, in which:

20 Figures 1(a), 1(b), and 1(c) illustrate selected steps of an exemplary method of manufacturing a security device according to an embodiment of the invention in cross section, Figure 1(d) shows an exemplary security device manufactured to this method, in cross section under unpolarised light, Figures 1(e) and 1(f) show this exemplary security device, in cross section under polarised light;

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Figures 2(a), 2(b), and 2(c) illustrate selected steps of a further exemplary method of manufacturing a security device according to an embodiment of the invention in cross section, Figure 2(d) shows an exemplary security device manufactured to this method, in cross section;

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Figure 3 illustrates an exemplary method of manufacturing a security device according to an embodiment of the invention in cross section;

Figures 4 and 5 depict two further embodiments of security devices according to the present invention in cross section;

Figure 6(a) and 6(b) show a face of an exemplary security document under unpolarised light and polarised light respectively;

Figures 7, 8 and 9 show three exemplary security documents carrying security devices in accordance with embodiments of the present invention, a) in plan view and b) in cross section; and

Figure 10 shows a further embodiment of an security document carrying a security device in accordance with embodiments of the present invention, a) in front view, b) in back view and c) in cross section.

15

DETAILED DESCRIPTION

The methods described within this document allow for the creation of covert, personalised security features which are only apparent under polarised light, e.g. light emitted by an LCD screen in a computer monitor, television or mobile telephone. Preferably, these security devices or the like are manufactured by applying a layer of birefringent liquid crystal onto a substrate using a thermal transfer method.

Figures 1(a), (b), and (c) show three steps in cross section of a sheet fed process for manufacturing security devices 10, the final security device 10 produced using this method being shown in Figure 1(c). The visual effect of this security device 10 is discussed below with reference to Figures 1(d), 1(e) and 1(f). As shown in Figures 1(c) to 1(f), the security device 10 comprises a substrate 12 and a layer of cured birefringent liquid crystal 24 in a first pattern 24a which is provided to a first side 12a of the substrate 12.

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As illustrated in Figure 1(a), there is first provided a transfer assembly 20 comprising a carrier layer 22 and a cured birefringent liquid crystal layer 24. The

carrier layer 22 comprises opposed first 22a and second 22b sides. The liquid crystal layer 24 is carried by the carrier layer 22, such that the liquid crystal layer 24 is provided in contact with the first side 22a of the carrier layer 22. The carrier layer 22 comprises polyethylene terephthalate (PET).

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Also provided is a substrate 12 (i.e. a substrate assembly), to which the liquid crystal 24 will be applied. The substrate 12 comprises PET polyethylene terephthalate (PET) and comprises opposing first 12a and second 12b sides (i.e. surfaces). However, any other suitable material able to bond to and carry the liquid crystal material 24 may be used. The substrate 12 is initially separate from the transfer assembly 20.

In a second step, shown in Figure 1(b), the transfer assembly 20 is brought into contact with the substrate assembly such that the liquid crystal layer 24 is in contact with the side 12a of the substrate 12. As will be seen from the figure, at this stage the liquid crystal layer 24 is positioned between and in contact with both the first side 22a of the carrier layer 22 and the first side 12a of the substrate 12.

Subsequently, a first pattern of the liquid crystal layer 24 is then heated using a thermal print head (not shown), as indicated by arrows H in Figure 1(b). This heat H is applied to the second side 22b of the carrier layer 22 and transmitted through the transfer assembly 20 to the liquid crystal layer 24. The application of heat to the liquid crystal layer 24 causes an increase in the temperature of the regions of liquid crystal 24. This results in the heated regions 24a of liquid crystal 24 being fixed or bonded to the substrate 12.

Consequently, when the transfer assembly 20 is removed from being in contact with the substrate 12, the heated regions 24a of the liquid crystal layer 24 are fixed to the first side 12a of the substrate 12, and release (i.e. break away or detach) from the carrier layer 22 and the adjacent unheated regions 24b of the liquid crystal layer 24. The unheated regions 24b, which are arranged in a second pattern which is the negative of the first pattern, remain in contact with or attached to the remaining components of the transfer assembly 20.

Hence, the substrate 12 of the security element 10 is provided with a birefringent liquid crystal layer 24 in a first pattern 24a. This security element 10 created once the transfer assembly is separated from the substrate assembly (i.e. the carrier layer 22 and the unheated regions 24b of liquid crystal are separated or detached from the substrate 12 and the heated regions 24a of liquid crystal) is shown in Figure 1(c).

Figures 1(d), 1(e) and 1(f) illustrate the visual effect of a security element 10 manufactured according to the method described above with relation to Figure 1(a) to (c) when seen through a separate linear polariser 14 by an observer at two positions O_1 and O_2 . Figure 1(d) shows the security element under unpolarised light. Figures 1(e) and 1(f) show the security element under linearly polarised light. The linear polariser will have a primary axis and an orthogonal secondary axis, wherein light which is polarised or aligned along the primary axis will pass through the polariser, whilst light which is polarised along a perpendicular secondary axis will be blocked by the polariser.

The security element 10 comprises liquid crystal regions 24a which rotate the polarisation of incident light by 90 degrees. This provides a strong visual effect. Nevertheless, a similar (albeit weaker) visual effect will also be seen if the liquid crystal region rotates the polarised light exiting the liquid crystal layer by any non-zero angle relative to the incident light. As described above, the rotation provided by the liquid crystal regions 24a is most easily controlled by varying the thickness of these regions 24a.

In all three figures, light L directed towards position O_1 is incident on a region of the security device 10 which is not provided with any liquid crystal 24 (i.e. light reaching the observer at O_1 has not passed through any liquid crystal material 24), whereas light directed towards position O_2 is incident on a region of the device 10 which is provided with liquid crystal 24 (i.e. light reaching the observer at O_2 has passed through a region of liquid crystal 24a which was heated and transferred from the transfer assembly 20 to the substrate 12). Light L which has passed through the security device 12 reaches the linear polariser 14 and is

either blocked or transmitted through the polariser 14 depending on its polarisation.

Figure 1(d) shows the security element 10 and polariser 14 when seen in transmission using unpolarised light L (e.g. natural light or sunlight). The unpolarised light L vibrates in substantially all directions randomly. As such, the incident light L may be notionally divided into two orthogonal components with respect to the polariser 14 (i.e. components which vibrate in perpendicular directions and at 90 degrees to one another), herein termed L_0 and L_{90} , wherein light with polarisation L_0 is polarised along (i.e. vibrates in) the primary axis of the polariser 14 and may pass through the polariser 14, whilst light with polarisation L_{90} is polarised along (i.e. vibrates in) the secondary axis of the polariser 14 and is blocked by the polariser 14.

Therefore, of the light L which is directed towards position O_1 (i.e. light which does not pass through liquid crystal material 24), light L_0 which is aligned along the primary axis of the polariser 14 is transmitted through both the security device 10 and the polariser 14 and reaches the observer, whereas the light L_{90} which is aligned along the secondary axis is blocked by the polariser 14, as shown in the figure.

In contrast, light L which is directed towards position O_2 passes through an overlying liquid crystal region 24a and is rotated by 90 degrees. Hence, incident light L_0 which is aligned to the primary axis of the polariser 14 is rotated by the liquid crystal regions 24a and exits the regions 24a and the security device 12 as light L_{90} which is aligned to the secondary axis of the polariser 14, and vice versa (i.e. L_{90} is rotated to L_0 by the liquid crystal layer).

Subsequently, as the light L reaches the polariser 14 light L_0 is transmitted through the polariser 14 and reaches the observer, whereas light L_{90} which is aligned along the secondary axis is blocked by the polariser 14, as shown in the figure.

Therefore, as shown in Figure 1(d), under unpolarised light L, light L_0 which is aligned to the primary axis of the polariser 14 is transmitted to an observer at both position O_1 and O_2 but L_{90} is blocked. Hence, the regions of the security device 10 provided with liquid crystal material 24a and the regions without liquid crystal appear substantially identical to an observer under unpolarised light L as similar levels of L_0 arrive at an observer at all points. Thus the security device 10 exhibits a substantially uniform visual appearance under unpolarised light L.

Figure 1(e) shows the security element 10 and the polariser 14 under linearly polarised light L_0 which is aligned along the primary axis of the polariser 14.

The light L_0 which is directed to an observer at O_1 passes through the security device 10 without being rotated and is transmitted through the polariser 14 as it is aligned with the primary axis of the polariser 14. However, light L_0 which is directed to an observer at O_2 is rotated by 90 degrees by the layer of liquid crystals 24a and exits the security device as light L_{90} which is polarised along the secondary axis of the polariser 14. Hence when the light L_{90} reaches the polariser it is blocked and does not reach the observer at O_2 .

In summary, the incident light L_0 is transmitted through the security device 10 and the polariser 14 in regions of the security device 10 without liquid crystal, whereas in regions 24a of the security device which are provided with a liquid crystal layer the light L_0 is rotated and subsequently blocked by the polariser 14. Therefore regions of the security device with liquid crystal regions 24a appear darker than areas of the security device without liquid crystal material, which appear relatively light or bright. This contrast between the light regions of the device 14 (without liquid crystal) and dark areas of the device (with liquid crystal) provides a strong visual effect which is readily seen by an observer.

Figure 1(e) shows the security element 10 and the polariser 14 under linearly polarised light L_{90} which is aligned along the secondary axis of the polariser 14.

The light L_{90} which is directed to an observer at O_2 passes through the security device 10 without being rotated and is blocked through the polariser 14 as it is

aligned with the secondary axis of the polariser 14. However, light L_{90} which is directed to an observer at O_2 is rotated by 90 degrees by the layer of liquid crystal 24a and exits the security device as light L_0 which is polarised along the primary axis of the polariser 14. Hence when the light L_0 reaches the polariser 14 it is allowed to pass and reaches an observer at O_2 .

Thus, regions of the security device 10 with liquid crystal regions 24a appear relatively bright under light L_{90} which is polarised in the secondary axis of the polariser 14, whilst areas of the security device 10 without liquid crystal appear relatively dark. This again offers a strong visual effect to an observer.

Hence, the visual effect of the security device 10 seen under light L_0 which is polarised in the primary axis of the polariser 14 is a negative image of the visual effect of the security device 10 under light L_{90} which is polarised along the secondary axis of the polariser 14.

Therefore, the visual or optical appearance of the security device 10 varies as the linear polariser 14 is rotated relative to a linearly polarised light source. Specifically, as either the incident light is rotated or the polariser is rotated the areas which were originally dark will become lighter, whilst the areas which were originally light will become darker. This can be contrasted with traditional optically variable effects demonstrated by conventional security devices, where the appearance of the security device will vary depending on the viewing angle (i.e. the angle between an observer and the normal of a security device which is perpendicular to a surface of the device).

As discussed above, the covert visual effect exhibited by security device 10 shown in Figures 1(c) to 1(f) is only visible when viewed under transmitted linearly polarised light through a linear polariser 14 which is provided separately to the security device 10. However, equally a polariser may be formed integrally within a security device, e.g. as layer within a security device, avoiding the need to provide such the polariser separately. However, in such cases the security device will be single-sided.

Figures 2(a), 2(b) and 2(c) show in cross section steps of a sheet fed process for manufacturing security devices 30 which comprise integral linear polariser layers. A security device 30 manufactured according to this method is shown in Figure 2(c). As will be seen from the figure, this security device 10 comprises a substrate layer 12, a polariser layer 14 and a layer of cured birefringent liquid crystal 24 provided in a first pattern 24a. The polariser 14 is provided between the substrate 12 and the liquid crystal 24, such that a first side of the polariser 14 is provided in contact with the substrate 12 and the liquid crystal 24 is provided in contact with an opposing second side of the polariser 14. In other words, the substrate initially carries a polariser 14, and in use carries a polariser 14 and overlapping regions of liquid crystal 24.

As illustrated in Figure 2(a), there is first provided a transfer assembly 20 comprising a carrier layer 22, a cured birefringent liquid crystal layer 24 and an alignment and primer layer 26 positioned between the carrier layer 22 and the liquid crystal layer 24. The carrier layer 22 has opposed first 22a and second sides 22b. The liquid crystal layer 24 is provided in contact with the alignment layer 26, which in turn is provided in contact with a first side 22a of the carrier layer 22. Thus the carrier layer 22 carries the liquid crystal layer 24 and the alignment and primer layer 26. In the drawing the carrier layer 22 is formed of polyethylene terephthalate (PET). The alignment and primer layer 26 comprises Elvanol (RTM) produced by Kuraray, which acts as both an alignment layer (aligning liquid crystal molecules in the adjacent liquid crystal layer 24) and a primer layer (being arranged to allow the liquid crystal 24 to cleanly detach from the transfer assembly when heated by a thermal print head, as discussed below).

In addition, there is provided a substrate assembly comprising a substrate 12 with opposed first 12a and second 12b sides and a polariser 14. The substrate comprises opposed first 12 and second 12b sides. The polariser 14 is arranged in contact with the first side 12a of the substrate 12, such that the substrate 12 carries the polariser 14. The assembly comprising the substrate 12 and the polariser 14 is initially separate from the transfer assembly 20. In the drawing the substrate 12 is formed of polyethylene terephthalate (PET).

In a second step, shown in Figure 2(b), the transfer assembly 20 is brought into contact with the polariser 14 such that the liquid crystal layer 24 is in contact with a free side of the polariser 14, i.e. the side of the polariser which is not in contact with the substrate 12, as shown in the figure. As will be seen from the figure, at this stage of the manufacturing process the liquid crystal layer 24 is positioned between the carrier layer 22 and the substrate 12.

Subsequently, a first pattern of the liquid crystal layer 24 is then heated using a thermal print head (not shown), as indicated by the arrows H in Figure 2(b), such that the temperature of the regions 24a of liquid crystal layer 24 corresponding to first pattern is increased. This heat H is applied to the second side 22b of the carrier layer 22 and transmitted through the carrier layer 22 and the alignment and primer layer 26 to the liquid crystal layer 24. The application of heat to the liquid crystal layer 24, and the increase in temperature of the first pattern of regions 24a of liquid crystal, causes the heated regions 24a of liquid crystal to fix or bond to the substrate 12.

The transfer assembly 20 is then removed from being in contact with the polariser 14 (i.e. the transfer assembly 20 and the substrate assembly are separated or disengaged), as shown in Figure 2(c). When the transfer assembly 20 is removed, the heated regions 24a of the liquid crystal layer 24 are fixed to the polariser 14, and release (i.e. break away or detach) from the alignment and primer layer 26 and the adjacent unheated regions 24b of the liquid crystal layer 24. The unheated regions 24b, which are arranged in a second pattern which is the negative of the first pattern, remain in contact with or attached to the remaining components of the transfer assembly 20.

Hence, the substrate 12 of the security element 30 is provided with a birefringent liquid crystal layer 24 in a first pattern 24a, as seen in Figures 2(c) and 2(d).

This security element 30, which combines a substrate 12, polariser 14 and regions of liquid crystal 24 exhibits a similar visual effect to the combination of a security element 10 and polariser 14 discussed with reference to Figures 1(d),

1(e) and 1(f). However, the device is single sided as the effect is only observed when the security device 30 is arranged such that the liquid crystal 24a is positioned between a polarised light source and the polariser 14. In other words, the effect is only seen when the device 30 is observed from the second side 12b
5 of the substrate 12 (and not when viewed from the first side 12a of the substrate).

In this arrangement unpolarised light (e.g. natural light) will be transmitted through the security device 10 in regions 24a with liquid crystal 24 and regions
10 without liquid crystal 24, such that the security element 10 will have a uniform visual appearance. In contrast, under linearly polarised light, the regions 24a with liquid crystal 24 may be distinguished from regions of the security device 10 without liquid crystal 24. Specifically, the regions of the security device 10 with liquid crystal 24a will appear either lighter (i.e. bright) or darker than the regions
15 of the security device 10 without liquid crystal 24.

Whether the regions with the liquid crystal 24 are lighter or darker than regions without liquid crystal 24 – and the relative lightness and darkness of these regions – will depend on the angle between the angle of polarisation of the polarised light and the primary angle of the polariser 14, as discussed above
20 with reference to Figures 1(d) to 1(f). However, because the polariser 14 is formed integrally within the security device 10 this can be achieved by rotating the security device 10 as a whole or by rotating the source of the unpolarised light.

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In summary, when viewed from the second side 12b of the substrate 12, the optical or visual appearance of the security device 10 will vary with separate regions of the device becoming brighter and darker relative to one another as the angle between the security device 10 and the unpolarised light is varied, for
30 instance by rotating the security device 10 relative to a stationary LCD screen emitting polarised light. Whereas, when viewed from the first side 12a of the substrate the security device 30 will exhibit a substantially uniform appearance under polarised and unpolarised light.

The processes for manufacturing a security device which are discussed above with reference to Figures 1 and 2 are sheet fed, such that the substrate and transfer assembly are formed as individual sheets. Typically, these sheet fed processes are highly accurate and allow good registration between layers and print workings but are slow.

In contrast, Figure 3 illustrates an exemplary web fed method for manufacturing a security device. Such web fed processes are typically quicker and offer a higher maximum throughput than corresponding sheet fed processes, however, it is typically more difficult to achieve high registration between separate print workings.

As shown in Figure 3 a transfer assembly 20 in the form of a continuous ribbon or web and a substrate 12 in the form of a continuous web pass between two pairs of nips or rollers 32a, 32b and 33a, 33b. The transfer assembly 20 comprises a carrier layer 22 with first 22a and second 22b opposed sides and a cured, birefringent liquid crystal layer 24, wherein the liquid crystal layer 24 is provided in contact with a first side 22a of the carrier layer 22 and the carrier layer carries the liquid crystal layer 24. The substrate 12 comprises two opposed sides, a first side 12a and a second side 12b. A thermal print head 34 is positioned between the two sets of rollers 32a, 32b and 33a, 33b.

The transfer assembly 20 and the substrate 12 move through the rollers 32a, 32b and 33a, 33b along a direction D.

The transfer assembly 20 and the substrate 12 are initially separate but are brought into contact with one another as they pass between the first, upstream set of rollers 32a, 32b, such that the liquid crystal layer 24 is in contact with the first side 12a of the substrate 12 and the first side 22a of the carrier layer 22 (i.e. the liquid crystal layer 24 is positioned between the substrate 12 and the carrier layer 22).

The combined web comprising the transfer assembly 20 and the substrate 12 then pass the thermal print head 34 which selectively applies heat H to the

second side 22b of the carrier layer (i.e. the side of the transfer assembly 20 opposing the liquid crystal layer 24). This heat H is transferred to the liquid crystal layer 24, raising its temperature. The action of this heat causes the heated regions 24a of the liquid crystal layer 24 to fix or adhere to the substrate 12.

Subsequently, the transfer assembly 20 and the substrate 12 pass through the second, downstream set of rollers 33a, 33b and are separated. As the transfer assembly and substrate are separated the heated regions 24a of the liquid crystal layer 24 detach from the transfer assembly 20 and the surrounding, unheated regions 24b of liquid crystal material 24 and remain fixed to the substrate. Consequently, the heated regions 24a of the liquid crystal layer 24 are transferred from the transfer assembly 20 to the substrate 12, whilst unheated regions 24b of the liquid crystal layer remain in contact with the carrier layer 22 on the transfer assembly 20.

Hence, the substrate 12 is provided with and carries a birefringent liquid crystal layer 24 in a first pattern 24a.

Once the substrate 12 has been separated from the transfer assembly 20 it may be "slit" (divided longitudinally, parallel to the direction of travel of the web) and "sheeted" (divided transversely, perpendicular to the direction of travel of the web) to create individual security devices, articles or documents, or sheets comprising multiple security devices, articles or documents for further sheet-based printing.

The individual security devices achieved by using this process will have substantially the same structure and will exhibit similar visual effects to the security devices 10 discussed with reference to Figure 1.

Equally, a security device with a structure corresponding to the device 30 shown in Figure 2(d) may be achieved using a web fed process by applying a polariser to the first side 12a of the substrate 12 at any point before the first rollers 32a shown in Figure 3.

In summary, security devices manufactured using all three of the methods discussed above with reference to Figures 1, 2 and 3 exhibit complex covert visual effects which are only seen under polarised light and which vary as the device or a polariser is rotated relative to the path of light emitted by a polarised light source.

In each of the above methods the liquid crystal layer 24 is assumed to be initially provided as a cured, birefringent liquid crystal (e.g. liquid crystal in a nematic phase with its molecules aligned). However, this is not essential. The method may include aligning the liquid crystal 24 so that it is birefringent and/or curing the liquid crystal at substantially any stage. For instance, the liquid crystal layer 24 may be aligned and/or cured before it is applied to the carrier layer 22 (i.e. before it is provided in a transfer assembly 20) or whilst part of the transfer assembly 20. Alternatively, the regions 24a of liquid crystal material 24 may be aligned and/or cured after they have been transferred from the transfer assembly 20 to the security device 10. Curing may be performed by exposing the birefringent liquid crystal to UV radiation e.g. by exposing the liquid crystal to ultraviolet light emitted by a mercury arc lamp with power of 120 W/cm for 1 second.

Additionally, or alternatively, further layers and components may be incorporated into security devices 10 manufactured using the methods above. For instance, during further method steps one or more of each of the following components may be provided or applied to the security device: print workings (e.g. containing information regarding denomination of a banknote, or the bearer or the issuer of an identify card or bank card); spacing layers; polariser layers; protective cover layers (to prevent damage to the device); anti-static or conductive layers (which prevent security devices, articles or documents from sticking or adhering to each other); opacifying layers; an alignment layer (to align liquid crystal molecules in an adjacent liquid crystal layer); and binder or primer layers (to modify or manage the bond between one or more other layers e.g. between the liquid crystal layer and an underlying layer). These layers may be provided (i.e. applied or affixed) in contact with or above either side of the substrate 12, or as

a sub-layer within a multi-layer substrate 1. Equally, a single layer may comprise the features or provide the functions of two or more of the layers listed above.

5 In preferred embodiments these layers are substantially visually transparent in the regions 24a of the security device 10 corresponding to the liquid crystal material 24 such that light may be transmitted through the device, with the exception of any polariser layers (which only transmit light of specific polarisation(s)) and opacifying layers (which absorb, scatter or reflect light).

10

Indeed, Figures 4 and 5 illustrate further embodiments of further security devices which may be manufactured using the methods discussed above. The devices shown in these figures exhibit similar visual effects to the security devices shown in Figure 2.

15

Figure 4 shows a security device 40 comprising a substrate 42 formed by a linear polariser (i.e. only light which vibrates parallel to a primary axis of the substrate 42 is transmitted through the substrate) with opposed first 42a and second 44b sides. A pattern of birefringent liquid crystal 44a is disposed on the first side 42a of the substrate 42. It will be seen that this structure is similar to the security device shown in Figure 2(d) except that the features of the substrate 12 and polariser 16 layers have been combined.

20

The security device 50 shown in Figure 5 comprises a substantially visually transparent substrate 52 is again similar to the security device shown in Figure 2(d). The security device comprises a substrate 52 with opposed first 52a and second sides 52b. A polariser layer 56 is disposed in contact with the first side 52a of the substrate 52, and a pattern of liquid crystal material 54 is arranged in contact with the polariser layer 56 above the first side 52a of the substrate 50 such that the polariser layer 56 is located between the liquid crystal 54 and the substrate 52. In addition, a protective, antistatic layer 58 is disposed over the regions of liquid crystal 54 and the polariser layer 56 (i.e. above the first side 52a of the substrate 52). This protective, anti-static layer 58 reduces the risk of damage (e.g. cutting or tearing) to the security device 50, acts to prevent would-

30

be counterfeiters from modifying or tampering with the liquid crystal 54, and prevents security devices 50 from sticking or adhering to one another when stacked.

- 5 Any of the security devices discussed above may be incorporated into a security article (e.g. a thread, strip or patch) or a security document (e.g. a banknote, passport or identity card).

Indeed, Figures 6(a) and (b) show photographs of a front face of an exemplary
10 security document 60 comprising a security device 62 comprising an integral linear polariser layer under transmitted unpolarised and linearly polarised light respectively. The security device 62 comprises regions of birefringent liquid crystal 62a, and may have been manufactured using any of the methods, or comprise any of the further components, discussed above.

15

The polariser layer (not shown) is located closer to the front face of the document 60 than the liquid crystal 62a. Therefore, a covert visual effect may be observed from the front of the document under linearly polarised light (as shown in Figure 6(b)). From the reverse side of the document 60 the security
20 device 62 will exhibit a substantially uniform appearance under polarised and unpolarised light.

In more detail, both figures show the front face of a security document 60 (an identify card) which comprises a security device 62. The security device 62 is
25 located in a substantially visually transparent window 64 formed by an aperture or gap formed in a substantially opaque opacifying layer 66. A plurality of print workings 68 are disposed on the security document 62.

As will be seen from the figures the print workings include items of information
30 regarding the issuer (i.e. name of country, country flag), items of information regarding the bearer (i.e. name, nationality, date of birth, place of birth, national identity number, portrait or photo) and items of information regarding the document 60 itself (i.e. the title of the document, date of issue). The items of information contained the print workings 68 comprise text 68a and graphics 68b.

In addition, it is evident that the print workings 68 comprise personalised information (i.e. information which is specific to this individual security document 60) and non-personalised information (i.e. information which is common to a number of security documents).

5

Each print working may be applied using any suitable printing method including gravure, flexographic, lithographic or intaglio printing. Alternatively any other suitable printing method may be used.

10 Under unpolarised light – as shown in Figure 6(a) – the security device 62 has a substantially uniform visual appearance. This is because although the regions of birefringent liquid crystal material 62a will rotate the polarisation of light transmitted through the device since unpolarised light vibrates randomly (i.e. substantially equally in all directions) approximately equal amounts of light are
15 transmitted through the security device 62 in regions with liquid crystal material 62a and regions without liquid crystal material.

In contrast, under linearly polarised light the regions of liquid crystal material 64a of the security device 62 will be readily seen by an observer, as shown in Figure
20 6(b).

Specifically, as shown, the incident linearly polarised light is polarised along the primary axis of the integral polariser. Therefore regions of the security device 62 without liquid crystal appear relatively bright as polarised light is transmitted
25 through the polariser and reaches an observer. In contrast, the regions of the security device 61 with liquid crystal 62a appear relatively dark because the liquid crystal material 62a rotates the polarised light so it is not polarised along the primary axis of the polariser. The relative brightness and darkness of the regions of the security device 62 with and without liquid crystal 62a will vary as
30 the security document 60 is rotated relatively to the path of light emitted by the polarised light source (not shown).

The boundaries of the regions of liquid crystal 62a define an item of information which is only visible under polarised light. This information is graphical, being a portrait of the bearer of the security document 60, as is evident from Figure 6(b).

5 Consequently, the information defined by the boundaries of the liquid crystal regions 62a is conceptually related to information defined by a print working 68 applied to the security document 60 since each defines a portrait of the bearer. This relationship between the information defined the boundaries of the liquid crystal regions 62a and the information defined by a print working 68 makes it
10 more difficult to imitate, counterfeit or tamper with the security document 60.

Further examples of documents of value (i.e. security documents) and techniques for incorporating a security device into said documents will now be described with reference to Figures 7, 8 and 9.

15

Figure 7 depicts an exemplary document of value 70, here in the form of a banknote. Figure 7(a) shows the banknote in plan view whilst Figure 7(b) shows the same banknote in cross-section along the line X-X'. In this case, the banknote is a polymer (or hybrid polymer/paper) banknote, having a transparent
20 substrate 71. Two opacifying layers 72a and 72b are applied to either side of the transparent substrate 71, which may take the form of opacifying coatings such as white ink, or could be paper layers laminated to the substrate 71.

The opacifying layers 72a and 72b are omitted across an area 78 which forms a
25 window within which the security device is located. As shown best in the cross-section of Figure 7b, a plurality of regions of liquid crystal material 74 are provided on one side of the transparent substrate 71, and a polariser 76 (i.e. a polarising filter) is provided on the opposite surface of the substrate 71. The liquid crystal regions 74 and polariser 76 are each as described above with
30 respect to any of the disclosed embodiments, such that – when viewed in transmission such that the liquid crystal 74 is positioned between a light source and the polariser 76 – the regions of the security document 70 without liquid crystal 74 visually contrast with regions of the security device 70 with liquid crystal 74 under transmitted polarised light, and wherein the relative darkness

and lightness of these regions varies as the document 70 is rotated relative to the direction that light propagates from a polarised light source.

5 The banknote may also comprise a series of windows or half-windows. In this case liquid crystal material may be applied to the first side of the transparent substrate 71 across the full extent of at least one window or half-window, such that visual appearance of said at least one window or half window will contrast with the visual appearance of the remaining windows and/or half windows when seen under polarised light.

10

Figure 8 shows such an example, although here the banknote 80 is a conventional paper-based banknote provided with a security article 85 in the form of a security thread, which is inserted during paper-making such that it is partially embedded into the paper so that portions of the paper 82a and 82b lie
15 on either side of the thread. This can be done using the techniques described in EP0059056 where paper is not formed in the window regions during the paper making process thus exposing the security thread in is incorporated between layers 82a and 82b of the paper. The security thread 80 is exposed in window regions 88 of the banknote. Alternatively the window regions 88 may, for
20 example, be formed by abrading the surface of the paper in these regions after insertion of the thread. The security device is formed on the thread 85, which comprises a transparent substrate 85a with a pattern of birefringent liquid crystal 85b provided on one side and polariser 85c on the other. In the illustration, the liquid crystal material 85b is depicted as being disposed discontinuously in each
25 exposed region of the thread 85. However, in practice this may not be the case and the security device may be formed continuously along the thread 85. In addition, as shown the liquid crystal material is disposed in a similar pattern in each window region 88. However, security devices with a variety of complex visual appearances may be achieved using such a structure. For example
30 regions of liquid crystal material 85b defining different images or items of information (e.g. graphics, text, indicia) may be provided in each window 88. Equally, the orientation of the primary axis of the polariser layer 85c may vary from one window 88 to the next, or the birefringence of the liquid crystal 85b may vary between windows (e.g. by varying the thickness of the liquid crystal layer),

such that the relative appearance (brightness and darkness) of the portions of the security device with and without liquid crystal material 85b varies between windows.

5 In Figure 9, the banknote 90 is again a conventional paper-based banknote, provided with a strip element or insert 95. The strip 95 is based on a transparent substrate 63 and is inserted between two plies of paper 92a and 92b. The security device is formed by regions of birefringent liquid crystal 95b on one side of the strip substrate 95a, and a polariser layer 95c on the other. The paper
10 plies 92a and 92b are apertured across region 98 to reveal the security device, which in this case may be present across the whole of the strip 95 or could be localised within the aperture region 98.

A further embodiment is shown in Figure 10 where Figures 10(a) and 10(b) show
15 the front and rear sides of a security document 100 respectively, and Figure 10(c) is a cross section along line A-A'. Security article 105 is a strip or band comprising a security device according to any of the embodiments described above. The security article 105 is formed into a security document 100 comprising a fibrous substrate 102, using a method described in EP-A-1141480.
20 The strip 105 is incorporated into the security document 100 such that it is fully exposed on one side of the document 100 (Figure 10(a)) and exposed in one or more windows 108 on the opposite side of the document 100 (Figure 10(b)). Again, the security device is formed on the strip 105, which comprises a transparent substrate 105a with birefringent liquid crystal material 105b formed
25 on one surface and a polariser layer 105b formed on the other.

In Figure 10, the document of value 100 is again a conventional paper-based banknote and again includes a strip element 105. In this case there is a single ply of paper. Alternatively a similar construction can be achieved by providing
30 paper 102 with an aperture 108 and adhering the strip element 105 is adhered on to one side of the paper 102 across the aperture 108. The aperture may be formed during papermaking or after papermaking for example by die-cutting or laser cutting. Again, the security device is formed on the strip 105, which

comprises a transparent substrate 105a with birefringent liquid crystal material 105b formed on one surface and a polariser layer 105b formed on the other.

- 5 In the security documents 70, 80, 90 and 100 discussed above with reference to Figures 7 to 10 the polariser layer is arranged in contact with the opposing side of a transparent substrate to the liquid crystal layer. However, this is not essential. Instead the polariser layer may be arranged in contact with or above the same side of the substrate that the liquid crystal material is located on or above. Equally, in each of the examples discussed above the substrate may be
- 10 omitted and the liquid crystal may be applied directly to the polariser layer (i.e. the polariser layer is used as a carrier in place of the substrate), avoiding the need to provide a separate visually transparent substrate layer in the security documents and articles discussed above.
- 15 It is also worth noting that since the security device only exhibits the optical effect when viewed from one side, it is also advantageous to apply the device over a non-windowed substrate. Similarly, in the context of a polymer substrate, the device is well-suited to arranging in half-window locations.

CLAIMS

1. A method of manufacturing a security device, comprising the steps of:
providing a transfer assembly comprising a carrier layer and a liquid
5 crystal layer carried by the carrier layer;
bringing the liquid crystal layer into contact with a first side of a substrate
assembly, the substrate assembly comprising a substrate;
heating a first pattern of the liquid crystal layer such that regions of the
liquid crystal layer corresponding to the first pattern are fixed to the substrate
10 assembly; and
separating the unheated regions of liquid crystal material from the
substrate assembly;
wherein the remaining regions of the liquid crystal layer fixed to the
substrate assembly are birefringent or are made birefringent subsequent to the
15 fixing step; and
wherein the substrate assembly comprises a polariser configured to
prevent incident visible light waves of a predetermined polarisation passing
through the polariser.
- 20 2. The method according to claim 1, wherein the liquid crystal layer
comprises liquid crystals in a nematic phase.
3. The method according to either claim 1 or claim 2, comprising the further
step of aligning the liquid crystal layer or the regions of the liquid crystal layer
25 fixed to the substrate assembly, such that the respective liquid crystal layer or
regions are birefringent.
4. The method according to claim 3, wherein aligning the liquid crystal layer
or the regions of the liquid crystal layer fixed to the substrate assembly is
30 performed using an alignment layer placed in contact with the liquid crystal layer.
5. The method according to any of claims 1 to 4, wherein the transfer
assembly further comprises an alignment layer positioned between the carrier
layer and the liquid crystal layer, the alignment layer being adapted to align liquid

crystals within the liquid crystal layer such that the liquid crystal layer is birefringent.

6. The method according to either claim 4 or claim 5, wherein the alignment
5 layer comprises a polyvinyl alcohol or a polyimide.

7. The method according to any of claims 1 to 6, comprising the further step
of curing the liquid crystal layer or the regions of the liquid crystal layer fixed to
the substrate assembly using ultraviolet radiation to fix the internal structure of
10 the respective liquid crystal layer or regions.

8. The method according to any of claims 1 to 7, wherein the carrier layer
carries a primer layer positioned between the carrier layer and the liquid crystal
layer, the primer layer being adapted to regulate the adhesive force between the
15 liquid crystal layer and the carrier layer.

9. The method according to any of claim 1 to 8, wherein the primer layer
comprises a polyester resin, a vinyl resin or a polyvinyl alcohol.

20 10. The method according to any of claims 1 to 9, wherein the carrier layer
comprises an alignment and primer layer, the alignment and primer layer being
adapted to align liquid crystals within the liquid crystal layer such that the liquid
crystal layer is birefringent and to regulate the adhesive force between the liquid
crystal layer and the carrier layer.

25 11. The method according to any of claims 1 to 10, wherein the substrate
assembly comprises a receiving layer, the receiving layer being adapted to
enhance the adhesive force between the liquid crystal layer and the substrate
assembly.

30 12. The method according to claim 11, wherein the receiving layer comprises
polyvinylpyrrolidone or polyvinyl butyral.

35 13. The method according to any of claims 1 to 12, wherein the polariser
prevents at least 50% of incident visible light waves of a predetermined
polarisation from passing through the polariser, more preferably the polariser

prevents at least 75% of incident visible light waves of a predetermined polarisation from passing through the polariser, more preferably still the polariser prevents at least 90% of incident visible light waves of a predetermined polarisation from passing through the polariser.

5

14. The method according to any of claims 1 to 13, wherein the regions of the liquid crystal layer fixed to the substrate assembly are fixed in contact with or above a window in the substrate assembly.

10

15. The method according to any of claims 1 to 14, wherein heating the liquid crystal layer is performed using a thermal print head.

15

16. The method according to any of claims 1 to 15, wherein the carrier layer comprises opposed first and second sides and wherein liquid crystal layer is carried in contact with or above a first side of the carrier layer;

and wherein further the step of heating the liquid crystal layer comprises applying heat in the first pattern to the second side of the carrier layer.

20

17. The method according to any of claims 1 to 16, wherein method comprises a web-fed process.

18. The method according to any of claims 1 to 17, wherein the transfer assembly is a ribbon.

25

19. The method according to any of claims 1 to 18, wherein the first pattern defines a first item of information comprising any of: indicia, alphanumeric text, a letter or number, a symbol, a portrait, a logo or another graphic.

30

20. The method according to any of claims 1 to 19, comprising the further step of applying a print working to the substrate assembly and wherein the print working defines a second item of information comprising at least one of: indicia, alphanumeric text, a letter or number, a symbol, a portrait, a logo or another graphic.

21. The method according to claim 20, when dependent on claim 19, wherein the first and second items of information are the same, complementary or conceptually linked.

5 22. A method of manufacturing a plurality of security devices, wherein each security device is manufactured according to the method of any of claims 1 to 21 and wherein the first pattern is varied for each of said plurality of security devices.

10 23. A security device manufactured in accordance with the method of any of claims 1 to 22.

24. A security article comprising a security device manufactured in accordance with any of claims 1 to 22 and wherein the security article is
15 preferably a security thread, strip, foil, insert, transfer element, label or patch.

25. A security document comprising a security device manufactured in accordance with any of claims 1 to 22 or a security article according to claim 24, wherein the security document is preferably a banknote, cheque, passport,
20 identity card, driver's licence, certificate of authenticity, fiscal stamp or other document for securing value or personal identity.

26. A transfer assembly suitable for use in the method according to any of claims 1 to 25.

Fig. 1(a)

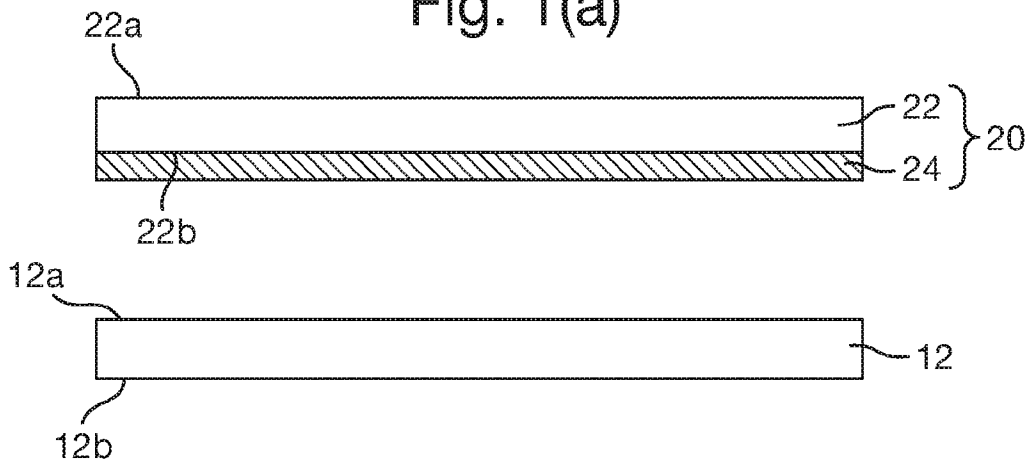


Fig. 1(b)

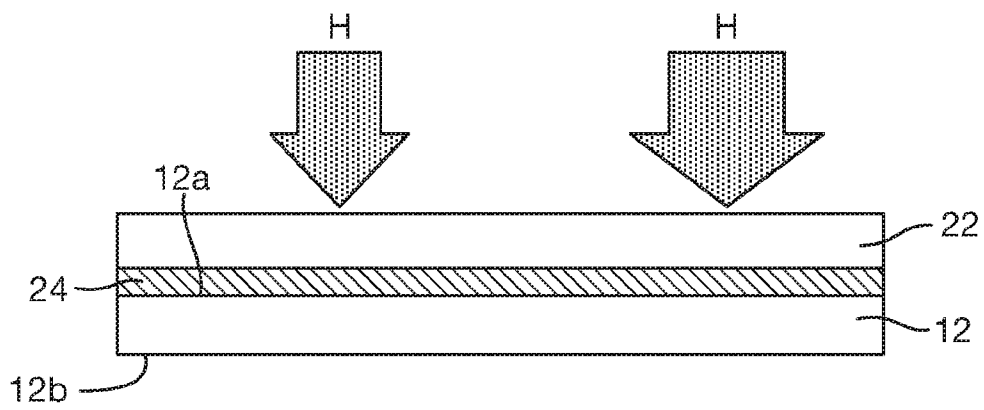
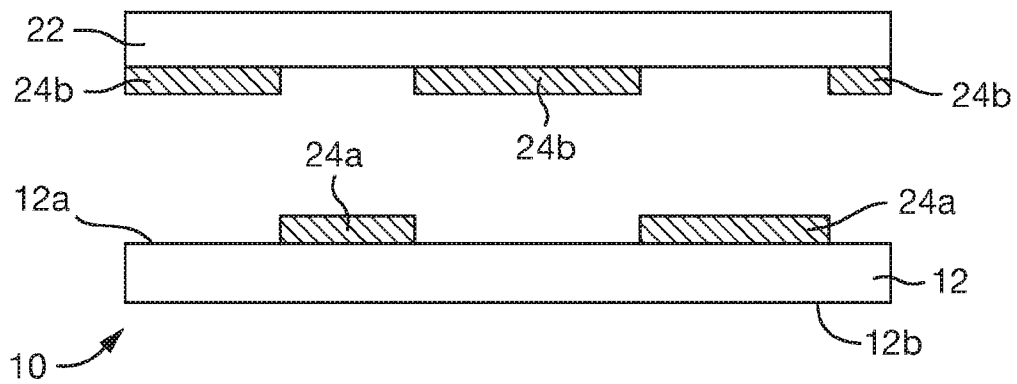


Fig. 1(c)



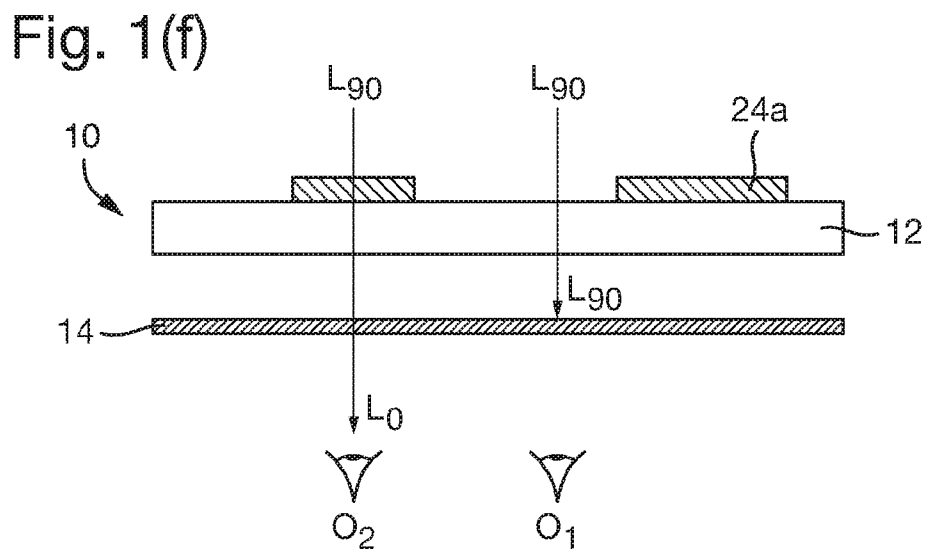
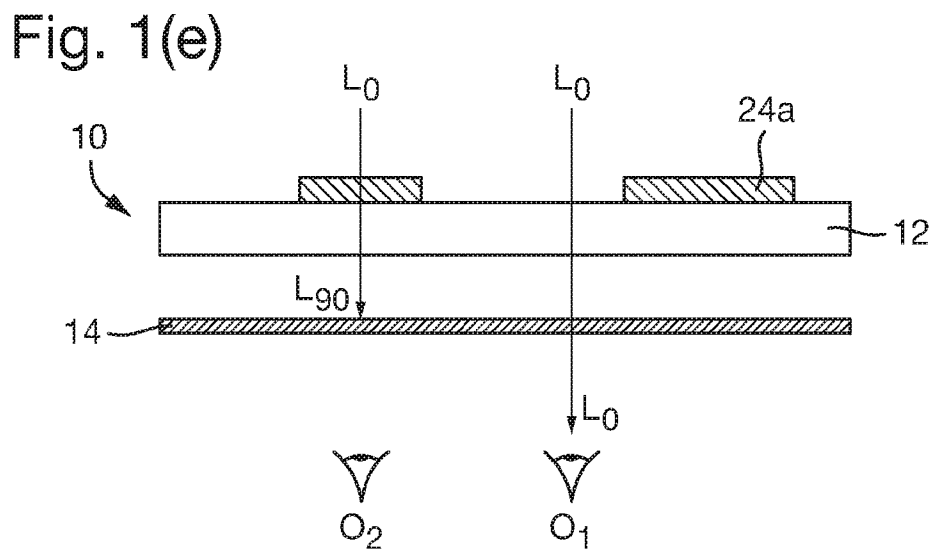
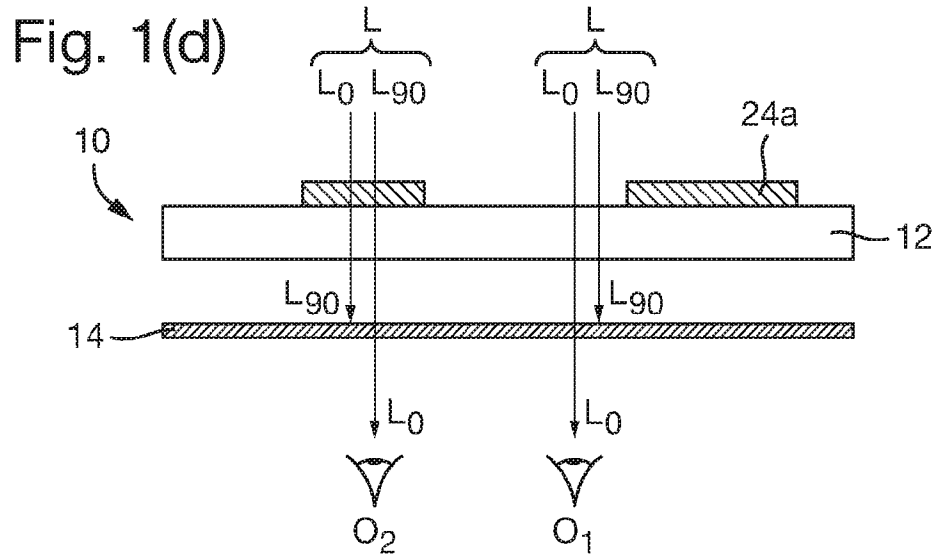


Fig. 2(a)

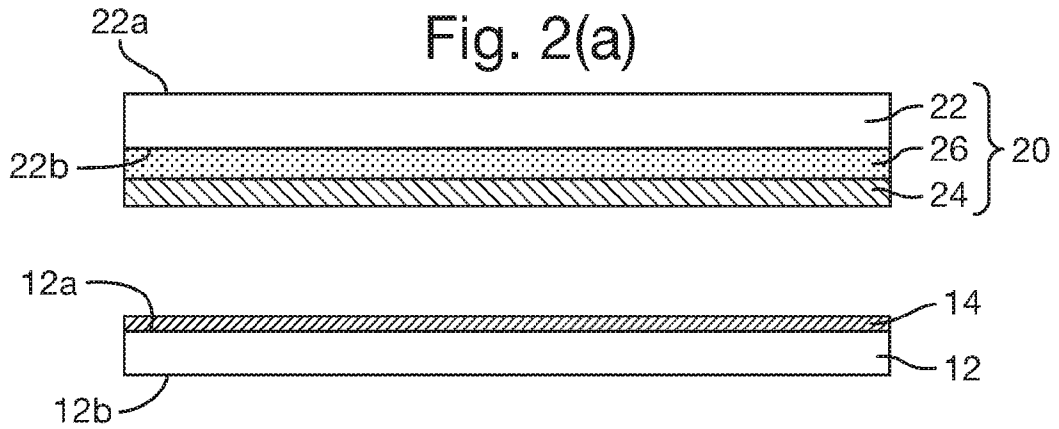


Fig. 2(b)

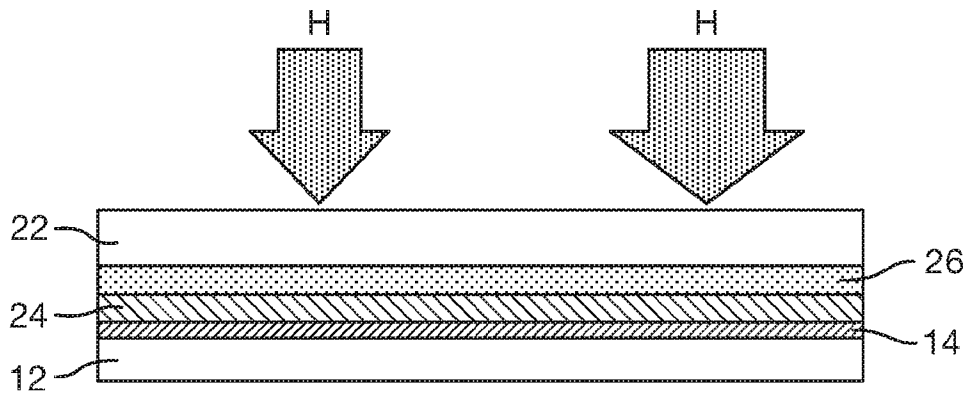


Fig. 2(c)

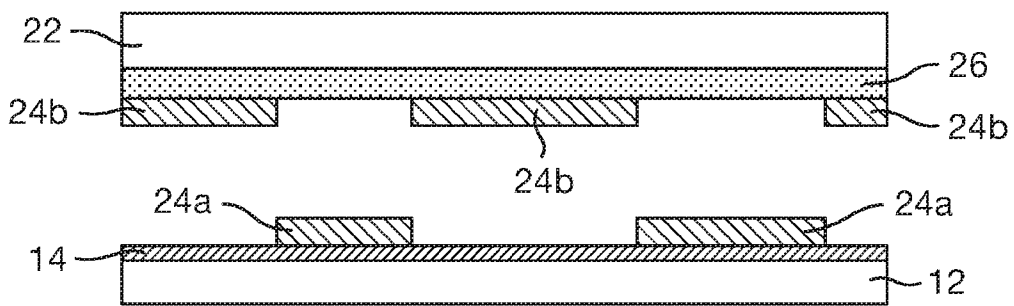


Fig. 2(d)

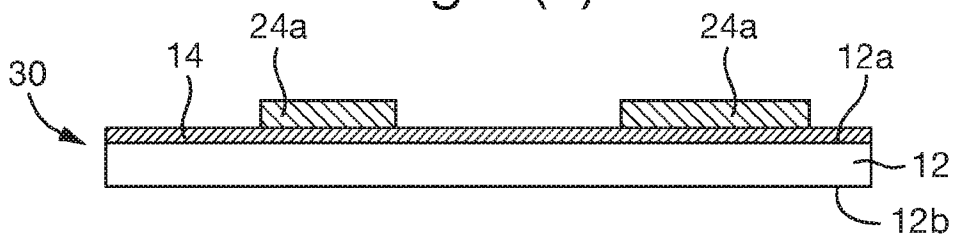


Fig. 3

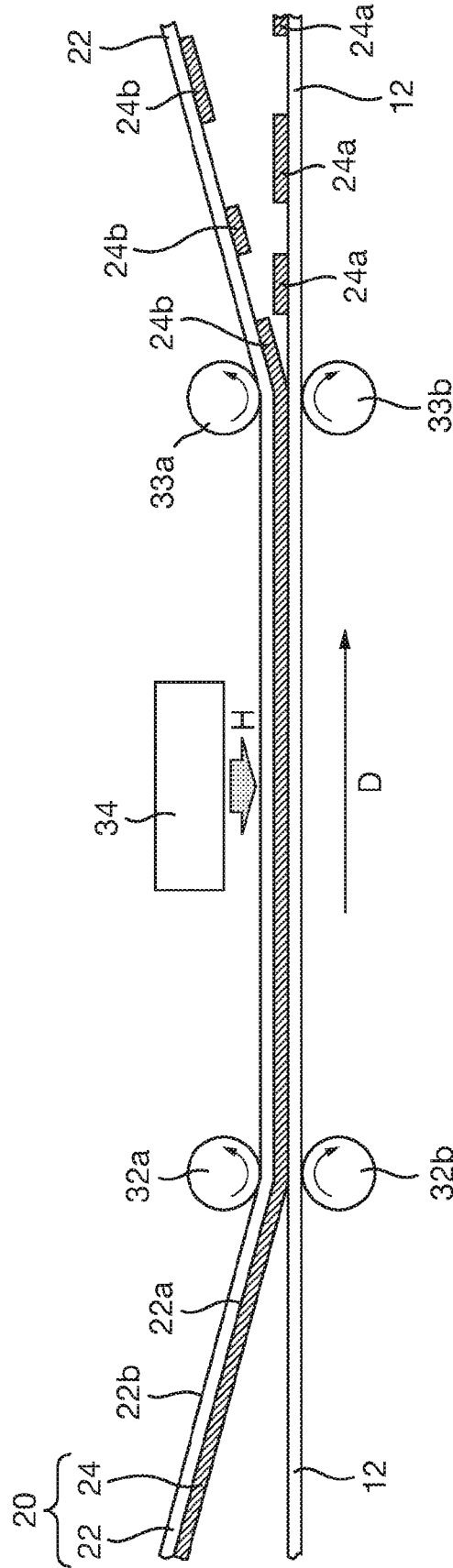


Fig. 4

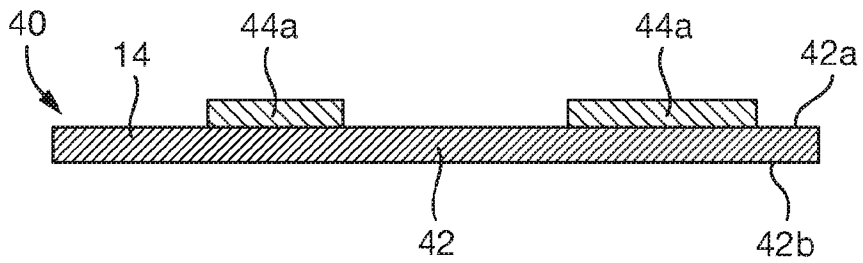


Fig. 5

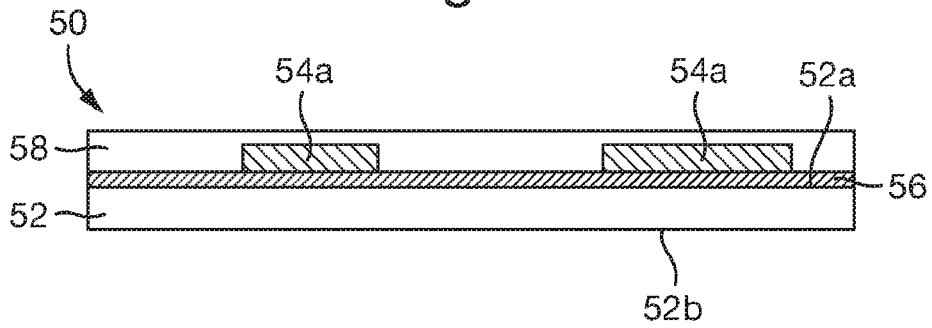


Fig. 6(a)

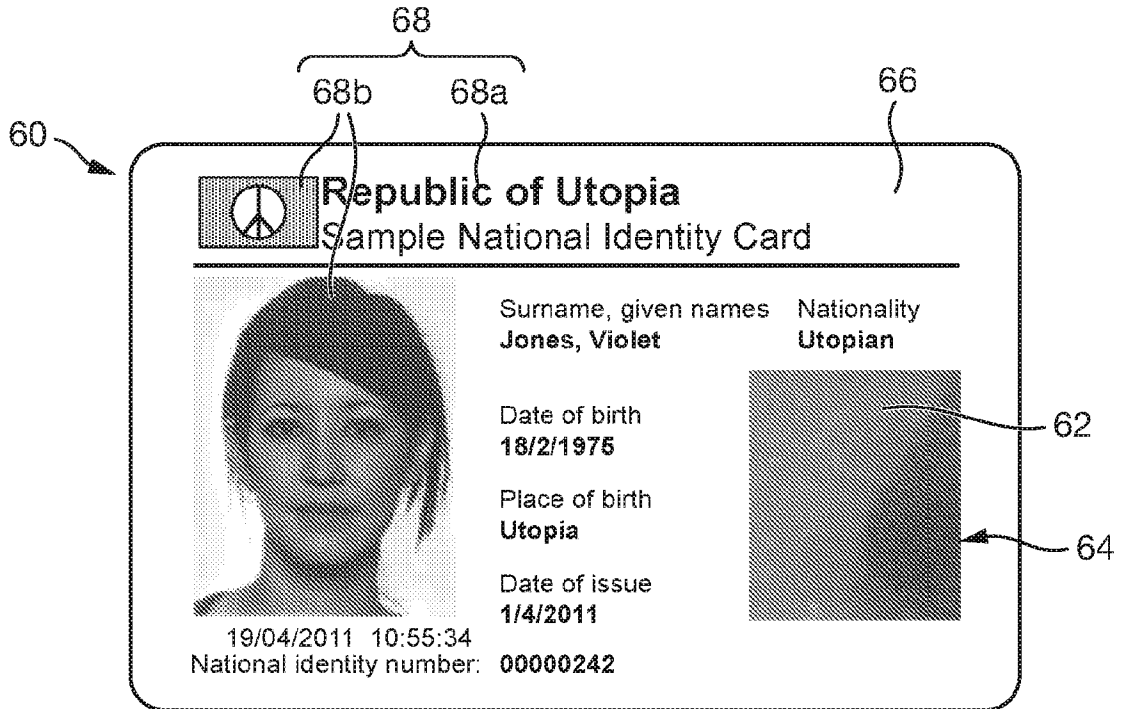


Fig. 6(b)

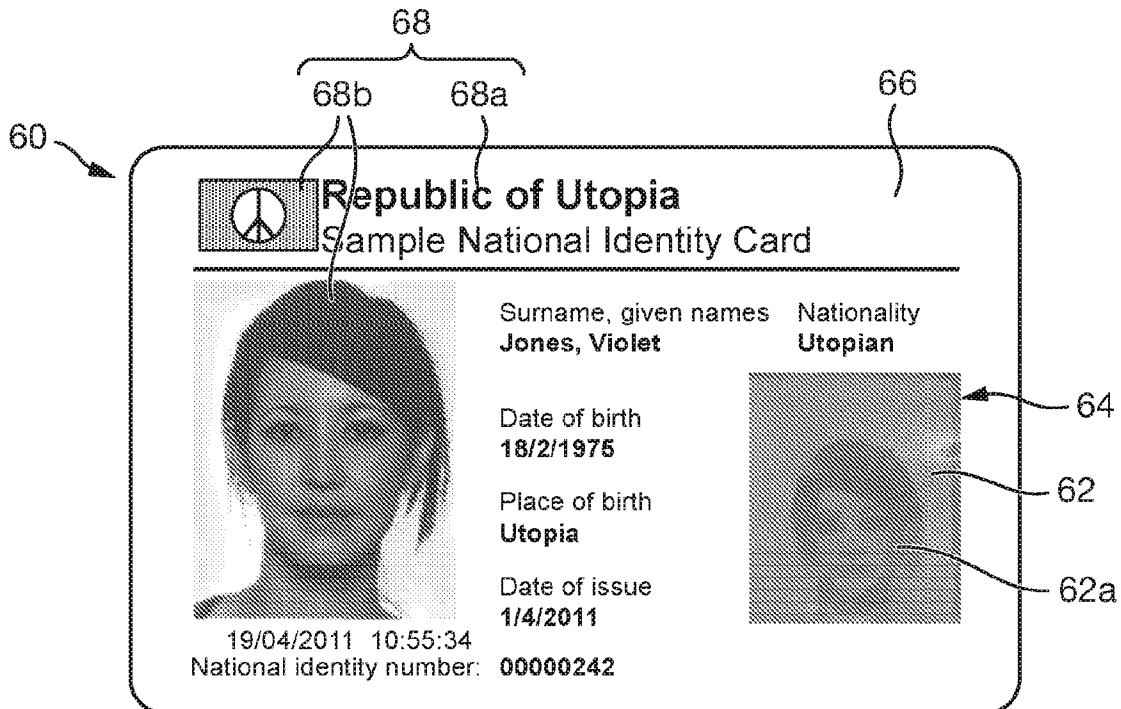


Fig. 7(a)

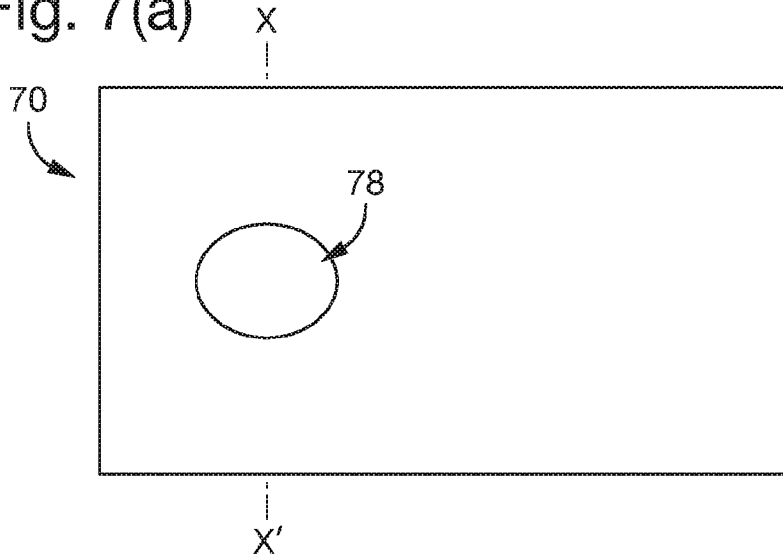


Fig. 7(b)

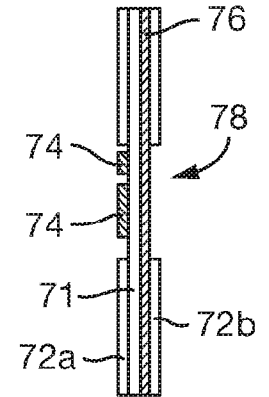


Fig. 8(a)

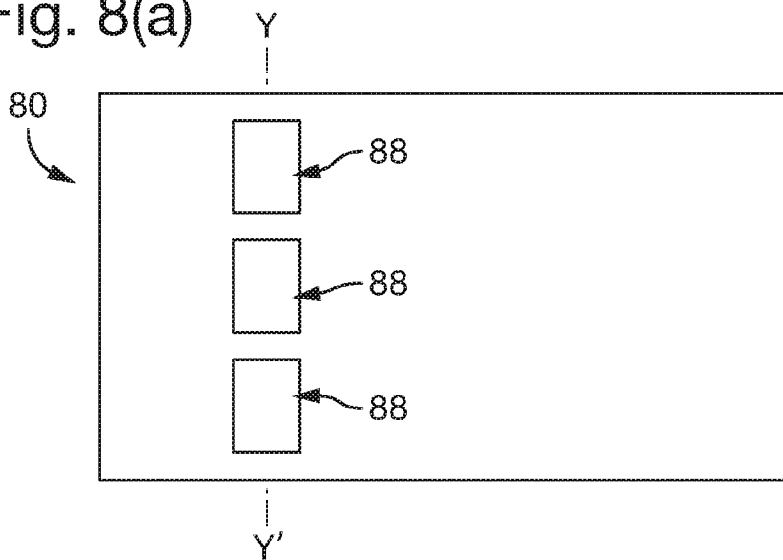


Fig. 8(b)

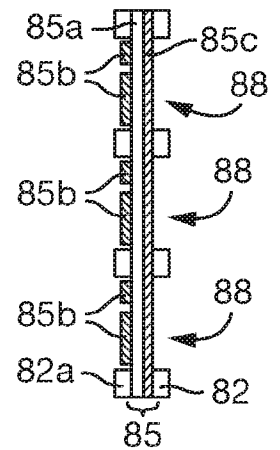


Fig. 9(a)

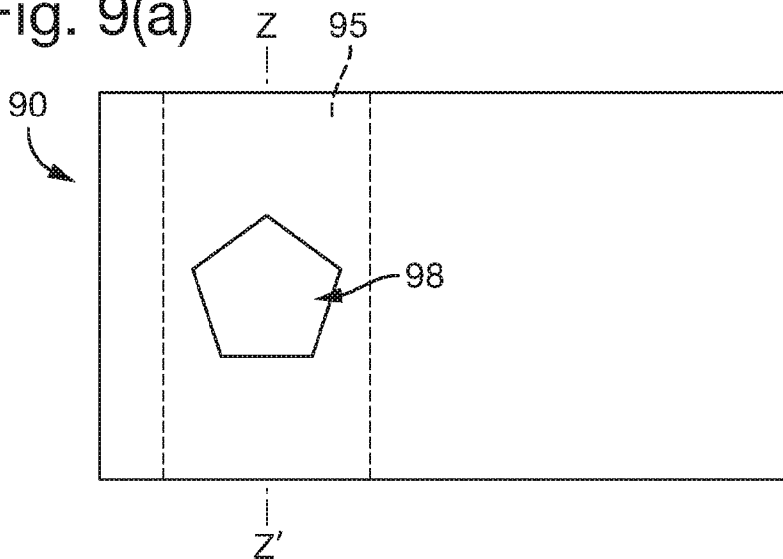


Fig. 9(b)

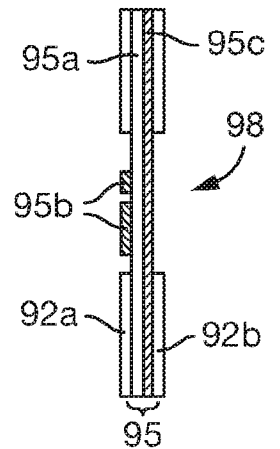


Fig. 10(a)

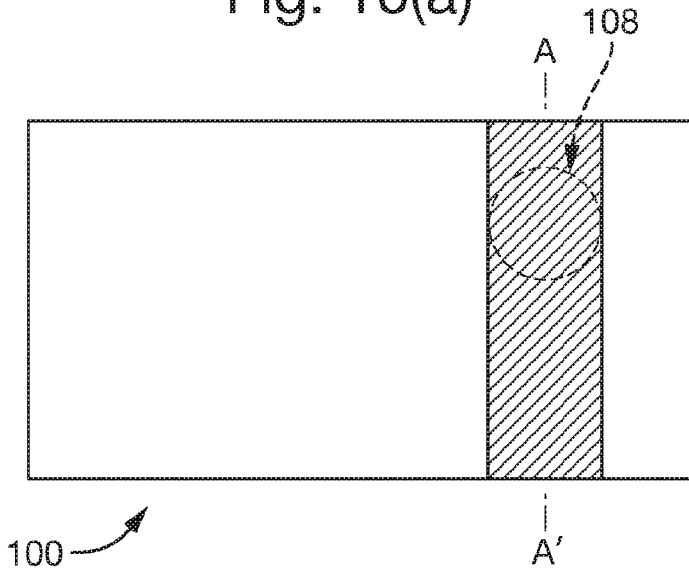


Fig. 10(b)

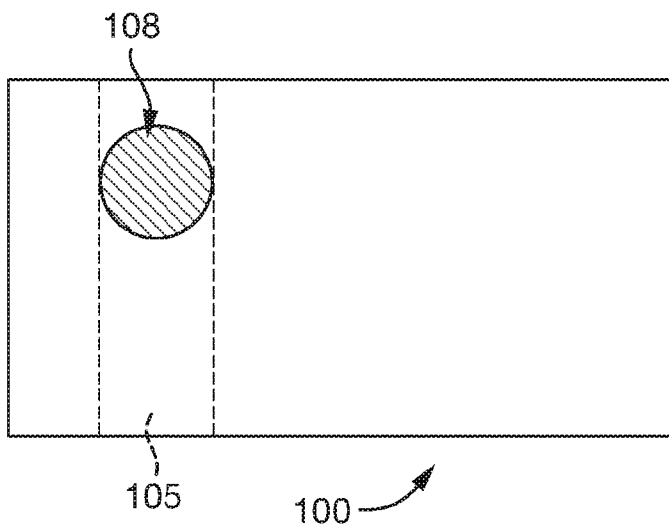
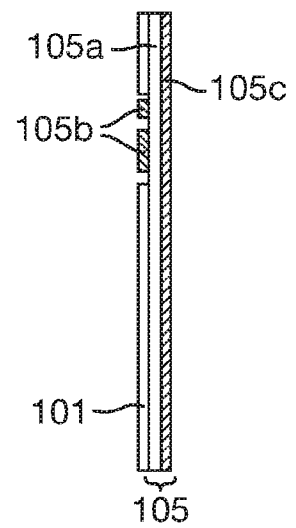


Fig. 10(c)



INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2018/053412

A. CLASSIFICATION OF SUBJECT MATTER
INV. B42D25/364 B42D25/391 B42D25/29 B42D25/455 B41M5/28
ADD.
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 B41M

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 3 163 335 A1 (ZEON CORP [JP]) 3 May 2017 (2017-05-03)	26
Y	paragraph [0009] - paragraph [0204]; claims 1-7; figures 1-13	1,3,4, 6-9, 11-16, 19-21, 23-25
X	----- JP 2014 024208 A (TOPPAN PRINTING CO LTD) 6 February 2014 (2014-02-06)	26
Y	paragraph [0027] - paragraph [0080]; claims 1-10; figures 1-13	1-3,5-7, 17,18, 23-25
	----- -/--	

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 13 March 2019	Date of mailing of the international search report 22/03/2019
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Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Seiler, Reinhold
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INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2018/053412

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2005/065962 A1 (SECURENCY PTY LTD [AU]; POWER GARY FAIRLESS [AU]; ZIENTEK PAUL [AU]) 21 July 2005 (2005-07-21)	23-25
Y	page 5, line 10 - page 12, line 23; claims 1-68; figure 5	1,3,4, 6-9, 11-16, 19-21, 23-25

X	WO 2016/141420 A1 (INNOVIA SECURITY PTY LTD [AU]) 15 September 2016 (2016-09-15)	23-25
Y	paragraph [0100] - paragraph [0103]; claims 1-58; figure 7b	1-3,5-7, 17,18, 23-25

X	US 2003/178609 A1 (HAMMOND-SMITH ROBERT [GB] ET AL) 25 September 2003 (2003-09-25)	26
	paragraph [0036] - paragraph [0100]; claims 1-26	

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/GB2018/053412

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			US 2017157972 A1
			WO 2016002765 A1

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			EP 1704060 A1
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			CN 107428193 A
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