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(54) Title: SECURITY PRINT MEDIA AND METHOD OF MANUFACTURE THEREOF

Fig. 1(a)

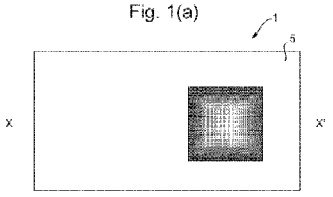


Fig. 1(b)

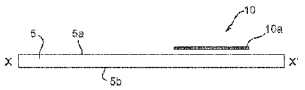


Fig. 1(c)

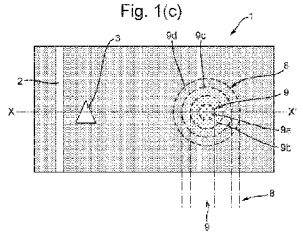
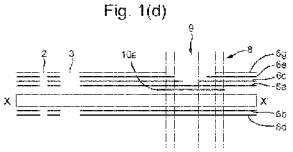


Fig. 1(d)



(57) Abstract: A security print medium is disclosed for forming security documents therefrom. The security print medium comprises a transparent or translucent polymer substrate having first and second opposing surfaces, and a plurality of overlapping opacifying layers disposed on the first and/or second surfaces of the polymer substrate, each of the opacifying layers being a layer of semi-opaque material. In a first region of the substrate a multi-tonal first image is exhibited by the plurality of overlapping opacifying layers in combination with one another, each of the plurality of overlapping opacifying layers having gap(s) in which the semi-opaque material of the layer is absent, the gap(s) of each layer being defined in accordance with a different respective sub-image, the sub-images in combination defining the multi-tonal first image. The number of opacifying layers overlapping one another at any one location varies across the substrate, the resulting variation in optical density of the plurality of overlapping opacifying layers in combination with one another giving rise to the multiple tones of the multi-tonal first image. The security print medium further comprises a print of a multi-tonal second image, different from the first image, on the first and/or second surfaces of the polymer substrate in a second region and covered from the point of view of an observer on a first side of the security print medium by the plurality of opacifying layers exhibiting the multi-tonal first image. The first and second regions at least partially overlap. When the security print medium is viewed by the observer in reflected light, the first image dominates the appearance of the overlapping area(s) of the first and second regions and when the security print medium is viewed by the observer in transmitted light, the second image dominates the appearance of the overlapping area(s) of the first and second regions.

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SECURITY PRINT MEDIA AND METHOD OF MANUFACTURE THEREOF

The present invention relates to security print media suitable for use in making security documents such as banknotes, identity documents, passports, certificates and the like, as well as methods for manufacturing such security print media, and security documents made from the security print media.

To prevent counterfeiting and enable authenticity to be checked, security documents are typically provided with one or more security elements which are difficult or impossible to replicate accurately with commonly available means, particularly photocopiers, scanners or commercial printers. Some types of security element are formed on the surface of a document substrate, for example by printing onto and/or embossing into a substrate such as to create fine-line patterns or latent images revealed upon tilting, whilst others including diffractive optical elements and the like are typically formed on an article such as a security thread or a transfer foil, which is then applied to or incorporated into the document substrate. A still further category of security element is that in which the security element is integrally formed in the document substrate itself. A well-known example of such a feature is the conventional watermark, formed in paper document substrates by controlling the papermaking process to as to vary the density of the paper fibres as they are laid down in accordance with a desired image. Techniques have been developed which can achieve highly intricate, multi-tonal watermarks which become visible when the substrate is viewed in transmitted light. Security elements such as watermarks which are integral to the document substrate have the significant benefit that they cannot be detached from the security document without destroying the integrity of the document.

Polymer document substrates, comprising typically a transparent or translucent polymer substrate with at least one opacifying layer coated on each side to receive print, have a number of benefits over conventional paper document substrates including increased lifetime due to their more robust nature and resistance to soiling. Polymer document substrates also lend themselves well to certain types of security features such as transparent windows which are more difficult to incorporate in paper-based documents. However, due to the non-fibrous construction of polymer

substrates, conventional watermarking techniques are not available and as such the potential for forming security elements integrally in the substrate itself is limited. Instead, for polymer security documents, security elements are typically applied after the document substrate has been manufactured, for example as part of a subsequent security printing process line, or by the application of a foil.

It would be desirable to provide a polymer document substrate – i.e. a security print medium, which can then be printed upon and otherwise processed into a security document – with an integral security feature, to enhance the security of the document substrate itself, and ultimately of security documents formed from it.

In accordance with the present invention, a security print medium for forming security documents therefrom comprises a transparent or translucent polymer substrate having first and second opposing surfaces, and a plurality of overlapping opacifying layers disposed on the first and/or second surfaces of the polymer substrate, each of the opacifying layers being a layer of semi-opaque material, wherein in a first region of the substrate a multi-tonal first image is exhibited by the plurality of overlapping opacifying layers in combination with one another, each of the plurality of overlapping opacifying layers having gap(s) in which the semi-opaque material of the layer is absent, the gap(s) of each layer being defined in accordance with a different respective sub-image, the sub-images in combination defining the multi-tonal first image, whereby the number of opacifying layers overlapping one another at any one location varies across the substrate, the resulting variation in optical density of the plurality of overlapping opacifying layers in combination with one another giving rise to the multiple tones of the multi-tonal first image, and the security print medium further comprising a print of a multi-tonal second image, different from the first image, on the first and/or second surfaces of the polymer substrate in a second region and covered from the point of view of an observer on a first side of the security print medium by the plurality of opacifying layers exhibiting the multi-tonal first image, the first and second regions at least partially overlapping, whereby when the security print medium is viewed by the observer in reflected light, the first image dominates the appearance of the overlapping area(s) of the first and second regions and when the security print medium is viewed by the observer in transmitted light, the second image dominates the appearance of the overlapping area(s) of the first and second regions.

The present invention also provides a method of making a security print medium, comprising: providing a transparent or translucent polymer substrate having first and second opposing surfaces; applying a print of a multi-tonal second image on the first and/or second surfaces of the polymer substrate in a second region; applying a plurality of overlapping opacifying layers onto the first and/or second surfaces of the polymer substrate, each of the opacifying layers being a layer of semi-opaque material, wherein in a first region of the substrate a multi-tonal first image is exhibited by the plurality of overlapping opacifying layers in combination with one another, each of the plurality of overlapping opacifying layers having gap(s) in which the semi-opaque material of the layer is absent, the gap(s) of each layer being defined in accordance with a different respective sub-image, the sub-images in combination defining the multi-tonal first image, whereby the number of opacifying layers overlapping one another at any one location varies across the substrate, the resulting variation in optical density of the plurality of overlapping opacifying layers in combination with one another giving rise to the multiple tones of the multi-tonal first image; wherein the plurality of overlapping opacifying layers cover the multi-tonal second image from the point of view of an observer on a first side of the security print medium, and the first and second regions at least partially overlap; whereby when the security print medium is viewed by the observer in reflected light, the first image dominates the appearance of the overlapping area(s) of the first and second regions and when the security print medium is viewed by the observer in transmitted light, the second image dominates the appearance of the overlapping area(s) of the first and second regions.

As in conventional polymer document substrates (security print media), the primary function of the opacifying layers (which are typically formed of a polymeric, non-fibrous, light-scattering material) is to render the majority of the document non-transparent and to provide a suitable background on which to print graphics, security patterns and other information as may be required on the finished security document. However, the presently disclosed security print media also provides a security feature which resembles the integral security features, such as watermarks, that are common in fibrous document substrates. Specifically, the presently disclosed security print media provides that, when viewed in reflection, a multi-tone first image is displayed to the viewer, but when held up to the light so as to be

viewed in transmission, provides that a different multi-tone image is revealed in the region of the multi-tone first image.

It will be appreciated that the print of the multi-tonal image and/or the opacifying layers need not be in direct contact with the surface of the polymer substrate, or each other. Rather, one or more additional (transparent or translucent) layers could be present between the polymer substrate, the print and/or the opacifying layers, such as a primer layer and/or the additional coloured layer(s) mentioned above, the print/opacifying layers still being considered disposed "on" the substrate surface.

The multi-tone first image is achieved by inserting one or more gaps in each of a plurality of the opacifying layers (which otherwise cover substantially all of the polymer substrate, that is, preferably at least 50% of the substrate, more preferably at least 80% and most preferably all of the remaining substrate). In each opacifying layer, the gap(s) are arranged according to a different respective sub-image, the cumulative effect of which is a variation in the optical density of the security print media across the region of the substrate, depending on the number of opacifying layers present at each point, resulting in the displayed multi-tone image. Locations in which fewer of the opacifying layers are present (i.e. where more of the opacifying layers have aligned gaps) will have a lower optical density, thereby appearing darker when the substrate is viewed against a dark surface, than other locations. Since relatively bright locations typically give the impression of being closer to the viewer, the resulting multi-tone image can provide a strong three-dimensional effect, especially where the sub-images are arranged to achieve a gradual change in optical density across the image (on a scale when viewed by the naked eye).

There may be one or more additional opacifying layers present which do not contribute to the multi-tone image, e.g. being entirely absent across the relevant region of the substrate or being provided uniformly across the region of the substrate. In addition, there could be more than one opacifying layer having gaps disposed in accordance with the same sub-image (provided there are at least two opacifying layers each having gaps disposed in accordance with different sub-images).

The sub-images will each be "versions" of the multi-tone first image in the sense that each will contribute to the definition of the same image, but any one of the sub-images by itself need not display all the elements which will be visible in the final multi-tone first image. Rather, each portion of the multi-tone first image will have a desired tone (or, analogously, optical density) relative to other portions of the multi-tone first image and each portion will be present (i.e. correspond to an area of opacifying material) or absent (i.e. correspond to a gap) in each sub-image in dependence on the desired tone of that portion. Hence, each sub-image shows selected portions of the multi-tone image depending on their desired tone. In this way, ultimately, each element of the multi-tone first image is built up by the presence or absence of each opacifying layer in the portion corresponding to the image element, the tone of the element resulting from the number of opacifying layers present. All of the sub-images are aligned with one another so that each portion of the multi-tone image has the same location in each sub-image.

In contrast to the multi-tone first image, the multi-tone second image is provided by a print located on the surface of the substrate and covered by the opacifying layers. The print is a layer of at least semi-transparent or semi-translucent material which, in its most basic form, affects the intensity of light passing through it by different amounts in different lateral locations to produce an appearance of a multi-tonal image.

It will be appreciated that the term "print" is intended to cover an image formed of a composition such as ink applied by any technique including conventional printing methods such as gravure, flexographic printing, lithography etc., but also ablation methods in which an all-over ink layer is applied and then selectively removed to leave an image, e.g. using a laser.

It will also be appreciated that while the plurality of overlapping opacifying layers cover the multi-tonal second image, at least in the area or areas where the first and second regions overlap, this does not necessarily mean that opacifying material of the plurality of opacifying layers is present over every point of the multi-tonal second image in the area of the overlap from the point of view of an observer on a first side of the security print medium. In some preferred embodiments, some gaps in each of the plurality of opacifying layers, defined in accordance with a different respective

sub-image, will align over the multi-tonal second image with those of the other opacifying layers in one or more places resulting in some portions of the second image having no opacifying material thereon. As will be described further below, the plurality of opacifying layers may be configured to disguise the appearance of the multi-tonal second image (in reflected light) without completely obscuring the presence of the print, e.g. to make use of the print to provide colour to parts of the first multi-tonal image.

In preferable embodiments, the print of the multi-tonal second image is a multi-coloured print, preferably comprising multiple print workings, and preferably comprising multiple print workings in different colours. In these embodiments, the print will affect the intensity of light to produce multiple tones, but will also have a filtering effect on the light to give light passing through the print at different locations a desired colour appearance in accordance with the multi-coloured, multi-tonal image. By providing a multi-coloured, multi-tonal image as the print, a very striking transition can be achieved when the viewer switches from viewing in reflection to viewing in transmission and vice versa, with the image displayed changing between a single colour version of a first image in reflection and a multi-coloured, multi-toned version of a second transmission. While preferable, a monochromatic, multi-toned print may instead be used. As mentioned, it is preferable that the multi-colour print is formed by multiple print workings applied to the substrate. This maybe in the form of a first half of the image being formed of a first working in a first colour and a second half of the working formed in a second colour, or of a second, and optionally a third and/or fourth, monochromatic print of the multi-tone image being applied over and in register with a first monochromatic print of the multi-tone image, in different colours, to produce a single multi-colour depiction of the multi-tone image. In some embodiments, the print of the multi-tonal second image comprises at least one halftone print working to introduce further complexity to the feature.

Preferably, the security print medium further comprises one or more opacifying layers disposed continuously across the print of the multi-tonal second image so as to cover the print of the multi-tonal second image from the point of view of an observer on the second side of the security print medium. While preferable, in alternative embodiments, the multi-tonal second image may also be uncovered from the point of view of an observer on the second side of the security print medium.

In some embodiments, each sub-image defines portions of the multi-tonal first image which have a tonal value falling within a respective tonal value range, the size of each respective tonal value range being different. That is, each sub-image is based on a different respective tonal value range. The tonal value of each point of the multi-tone image can be defined on an arbitrary scale relative to the darkest tone and lightest tone present in the multi-tone image (e.g. corresponding to tonal values of 100% and 0% respectively), or on an absolute scale as may be measured for example using a transmission densitometer such as the MacBeth TD932 (e.g. lightest tone portions having an optical density of 0.9, and darkest tone portions having an optical density of 0). The size of the different tonal value ranges may increase in constant steps, e.g. by 10% or by 20% where the scale is relative, or by 0.1 or 0.2 where the scale is absolute) from one sub-image to another. It should be noted that the sub-images do not need to be physically arranged on or applied to the substrate in the same order as that denoted by their respective tonal value ranges. The order in which the opacifying layers (and their respective sub-images) are arranged on the substrate is generally unimportant since it is the cumulative effect of the layers which produces the desired image.

Advantageously, when the tonal value ranges of the sub-images are ordered according to increasing size, each tonal value range falls within the tonal value range next in the sequence. For example, a first sub-image may define portions of the multi-tone image having a tonal value in the range 0% to 10%, a second sub-image may define portions having a tonal value in the range 0% to 20% (thereby including all the same portions as in the first sub-image, plus more), a third sub-image may define portions having a tonal value in the range 0% to 30%, and so on. In this way, the desired tone of each image portion will be provided by the cumulative effect of the sub-layers which define that portion.

In some preferred embodiments each or at least one of the sub-images will be a binary or “flat” image with no tonal variation: the opacifying material is either present or absent on a scale visible to the naked eye, with no intermediate areas. However, in more preferred embodiments, at least some of the sub-images are multi-tonal sub-images, preferably half-tone sub-images. In this way, multiple tones can be introduced within the sub-image itself, e.g. allowing for a gradual change from a

region of 100% opacifying material though a region in which the opacifying material is applied to a gradually decreasing proportion of the surface (on a scale too small to be appreciated by the naked eye) to a region in which the opacifying material is absent (i.e. a gap). This can be used to create a smoother transition between tones in the final multi-tone image, and more complex effects. For example, this allows for the creation of even more different tones in the final image than the number of different opacifying layers would itself permit.

The opacifying layers each preferably comprise a non-fibrous, polymeric material which will scatter light (as opposed to allowing clear light transmission therethrough), and will be translucent to a degree. In preferred examples, each individual opacifying layer may have an optical density in the range 0.1 to 0.5, more preferably 0.1 to 0.4, most preferably 0.1 to 0.3 (as measured on a transmission densitometer, with an aperture area equivalent to that of a circle with a 1mm diameter – a suitable transmission densitometer is the MacBeth TD932). The individual opacifying layers may or may not be of the same composition as one another – for example, in some preferred cases at least one of the opacifying layers will contain electrically conductive particles (desirable to reduce the effects of static charge), whereas others will not – but nonetheless, preferably, all of the opacifying layers are substantially the same colour as one another, most preferably a light and bright colour such as white (including off-white) or grey. In preferred implementations, the opacifying layers each have a brightness L* in CIE L*a*b* colour space of at least 70, preferably at least 80 and more preferably at least 90.

In some embodiments, the sub-images are configured such that a smaller number of the opacifying layers overlap one another at locations across the substrate corresponding to darker tones in the multi-tonal first image as seen in reflected light, relative to the number of opacifying layers which overlap one another at locations corresponding to lighter tones in the multi-tonal first image as seen in reflected light. Preferably, the plurality of overlapping opacifying layers includes at least three overlapping opacifying layers each having gap(s) defined in accordance with a different respective sub-image.

The security print medium could additionally include one or more opacifying layers which do not take part in the formation of the multi-tone image. Hence in some

preferred embodiments the security print medium further comprises one or more additional opacifying layers each comprising a layer of semi-opaque material disposed over substantially the whole area of the first and/or second region, the one or more additional opacifying layers each extending continuously across the first and/or second region. Alternatively, or in addition, the security medium may comprise one or more additional opacifying layers each comprising a layer of semi-opaque material disposed over substantially the whole area of the polymer substrate, the one or more additional opacifying layers each either extending continuously across the region of the substrate containing the multi-tonal first and second images or comprising a gap substantially across the first and/or second region. By providing a layer of opacifying material across the first and/or second region, the minimum opacity in those regions can be raised, with the opacifying layers formed as sub-images then varying the opacity above this minimum at different lateral locations. By providing a gap across the first and/or second region, the opacity of the document can be increased in regions where light transmission through the medium is not necessary for visibility of the multi-tonal second image. In many embodiments, it may be desirable to provide at least one opacifying layer on each surface of the substrate, e.g. to enable later printing thereon and/or to protect the substrate or control its surface texture.

Since the total opacity of the opacifying layers varies across the first region to form the first multi-tonal image, in some embodiments, when the security print medium is viewed by the observer in reflected light, the print of the second image is at least partly visible in (some of the) area(s) corresponding to gap(s) in at least one of the plurality of opacifying layers in the overlapping area(s) of the first and second regions. For example, in some embodiments the print may not be visible, or may be barely visible, in regions where the print is covered by opacifying material from each of the applied opacifying layers. In regions in which less opacifying material covers the print, as a result of one or more gaps being present in the overlying opacifying layers, the visibility of the print will increase according to the reduction in opacifying material covering the print, i.e. according to the number of aligned gaps over the print. Finally, the visibility of the print will be at a maximum where gaps in all of the opacifying layers align over the print. Advantageously, the opacifying layers may be configured to disguise the appearance of the second image in reflection, by

obscuring selected regions of the print, while allowing certain aspects of the print to remain visible.

It will be appreciated here that there is an important distinction between the visibility of the print of the multi-tonal second image, and the visibility of the multi-tonal second image itself. While the print of the multi-tonal image may be partly visible through gaps in the opacifying material in reflected light, e.g. revealing elements or small areas of the second image, the second image as a whole (e.g. its information content) should not be distinguishable by the viewer. In such embodiments, elements of the second image may be used to enhance the appearance of the medium in reflection while the first image still dominates the overall appearance.

For instance, in some embodiments, the print of the second image contributes a background to the first image in the overlapping area(s) of the first and second regions, and in particularly preferable embodiments, when the security print medium is viewed by the observer in reflected light, the colour of the print of the second image is visible in the overlapping area(s) of the first and second regions. For example, the multi-tonal first image may be selected to reveal a large percentage of the print, while not revealing any one large continuous area of the print. In this way, the detail of the second image, displayed by the print in transmission, may be disguised in reflection, and the print instead used to enhance the appearance of the first image across the region of the overlap by providing colour to the region of the overlap, which is particularly effective in embodiments in which the print is monochromatic. Embodiments in which the colour of the print is visible in the region of the overlap are particularly advantageous as the print can be used to replace the lithographic print layer, commonly applied to a security medium to provide regions of colour underneath an outer intaglio print applied when processing the security medium into a document. Embodiments which use the print to replace the lithographic print layer are particularly advantageous as the print is applied during formation of the security medium, before application of opacifying layers, and so can be precisely registered to other features, such as windows through the opacifying material.

The document designer will be able to ensure the print dominates the appearance of the medium in transmission by controlling the optical density and coverage of the

print and opacifying layers as appropriate. For example, one relevant consideration may be the coverage of opacifying coating having high opacity, which could appear as dark regions in transmission, possibly obscuring parts of the second image. Therefore, in some embodiments, the opacifying layers in combination have an optical density of at least 0.4 over at most 50%, preferably at most 30%, more preferably at most 20%, of the overlapping area(s) of the first and second regions (but preferably more than 0% of the overlapping area(s) of the first and second regions). Providing that the opacity of the opacifying coating is not high over a large area reduces the visibility of the opacifying coating in transmission, especially where the high opacity areas are non-continuous.

It may also be desirable to provide that the opacifying coating is present over a large proportion of the area of the overlap (even if with a low optical density) so as to hide a large proportion of the print in reflection. Therefore, preferably, the opacifying layers in combination have an optical density greater than substantially zero over at least 50%, preferably at least 70%, more preferably at least 80%, of the overlapping area(s) of the first and second regions. Providing that the opacifying coating is present with a low opacity in a large proportion of the overlap may help to hide the appearance of the print in reflection while ensuring good visibility of the print in transmission. While it is desirable to have a high proportion of the overlap with a low opacity coating to substantially hide the print in reflection, it is desirable that the print is still visible in at least some portions of the area of the overlap so as to enhance the appearance of the first image in reflection. Therefore, preferably, the opacifying layers in combination have an optical density of substantially zero over one or more parts of the overlapping area(s) of the first and second regions. Preferably, the optical density will be substantially zero over between 0% and 50% of the overlapping area(s) of the first and second regions, more preferably between 0% and 20%. In some embodiments, the opacifying layers in combination will be have an optical density of 0.05 in areas configured to reveal the print.

The security print medium could be configured such that, away from the region of the first multi-tonal image, at least one opacifying layer is present at every point across the substrate, so that the document substrate does not appear transparent. However, to add an additional level of security, in preferred embodiments, at least one transparent window region is formed by aligned gaps in each of the opacifying

layers (outside of the first region and preferably outside of the second region), the at least one transparent window region preferably substantially surrounding the multi-tonal first and second images.

The or each opacifying layer may be laid down via an application technique which results in no additional visible sub-structure to the layer beyond that defined by the sub-image, i.e. the opacifying material being present in a macroscopically uniform, homogenous layer across all regions outside the gaps defined by the sub-image. This will typically be the case where the layer is applied by gravure printing with a cell size too small for individual recognition by the naked eye. Thus, at least some of the opacifying layers are applied in the form of an array of screen elements which are too small to be individually discernible to the naked eye. However, in other preferred cases one or more of the opacifying layers may be laid down in the form of a visible screen. Hence, at least one of the sub-images is formed of an array of screen elements which are sufficiently large to be individually discernible to the naked eye, the size of the screen elements varying across the array to define the sub-image. For example the sub-image may be defined by line screen elements or dot screen elements, e.g. to give the appearance of an intaglio-printed pattern. Regardless of element size, preferably the opacifying layers are printed opacifying layers, preferably they are applied to the substrate by gravure printing. Also, preferably at least one of the opacifying layers comprises electrically conductive particles.

The security print medium may advantageously further comprises a raised pattern layer (e.g. of transparent or coloured ink) applied to the outermost opacifying layer on one or both sides of the substrate, the raised pattern layer comprising an array of screen elements which are sufficiently large to be individually discernible to the naked eye, the raised pattern layer preferably being tactile and/or of varying visibility depending on the viewing angle. For example, the pattern layer could be applied by intaglio printing. In a particularly preferred embodiment, such a raised pattern layer is provided in combination with a visibly-screened opacifying layer and the array of screen elements forming the at least one of the sub-images is arranged to visually cooperate with the array of screen elements forming the raised pattern layer. For example, the raised pattern layer could be provided across one area of the region containing the multi-tone first image and the screened opacifying layer across a

second, different area, the two areas merging into one another. This gives the impression of a continuous screened pattern at some viewing angles and not others.

To make best use of the ability of the multi-tone images to display distinct light and dark portions, and preferably different intermediate tones as well, it is particularly advantageous if the multi-tonal first image and/or the multi-tonal second image comprises an image of a three-dimensional object, preferably a geometrical solid or wireframe model, a person, an animal, a building or other architectural structure or a three-dimensional logo.

In embodiments, the first and second multi-tonal images need only partially overlap. However, to produce a more striking transition, it is preferable that one of the first region and the second region is contained completely within the other of the first and second region. For example, one image may frame the other or provide a background to the other. Alternatively, the first region and the second region may be substantially the same. In either case, it is preferable that one of the first and second regions is substantially the entire first and/or second surface of the substrate.

The method of making a security print medium already introduced above can be adapted to make any of the preferred features described above.

The invention further provides a security document comprising a security print medium as described above, and at least one graphics layer applied on the outermost opacifying layer(s) on the first and/or second surfaces of the polymer substrate. The security document could be for example any of: a bank note, an identification document, a passport, a licence, a cheque, a visa, a stamp or a certificate. A corresponding method of manufacturing a security document comprises making a security print medium in accordance with the above-described method; and applying at least one graphics layer to the outermost opacifying layer(s) on the first and/or second surfaces of the polymer substrate. Typically the step of applying at least one graphics layer to the outermost opacifying layers will be carried out in a separate manufacturing process (e.g. at a different manufacturing facility and possibly by a different entity) from the manufacture of the security print media itself. However, the at least one graphics layer may preferably be applied in

register with the multi-tone image in the opacifying layers so as to achieve a visual co-operation between the graphics layer and the multi-tone image. This can be achieved by using a sensor such as a camera system to detect the location of the multi-tone image and adjust the position of the applied graphics layer accordingly. The graphics layer can be applied using any available printing process such as gravure, flexographic, lithographic or intaglio printing, for example. The graphics layer may typically include security patterns such as fine line patterns or guilloches, information as to the nature of the security document such as denomination and currency identifiers for a banknote, and/or personalisation information such as a serial number on a banknote or bibliographic data of the holder on a passport.

Examples of security print media in accordance with the present invention will now be described with reference to the accompanying drawings, in which:

Figure 1 shows a first embodiment of a security print medium (a) in plan view, before application of any opacifying layers, (b) in cross-section, before application of any opacifying layers, (c) in plan view, after the application of opacifying layers, and (d) in cross-section, after the application of opacifying layers, layers of the security print medium being shown spaced apart for clarity;

Figures 2(a) to (c) show portions of different opacifying layers of the security print medium of Figure 1;

Figures 3(a) to (c) show portions of different opacifying layers of the security print medium of Figure 1 in a variant thereof;

Figure 4(a) shows an example of a raised pattern layer, and Figure 4(b) shows an example of an opacifying layer which may be provided to the security print medium of Figure 1 according to a variant thereof;

Figure 5 shows schematically a second embodiment of a security print medium, with each layer applied to the substrate being depicted individually in plan view;

Figure 6 shows schematically a third embodiment of a security print medium, with each layer applied to the substrate being depicted individually in plan view; and

Figure 7 shows a first embodiment of a security document (a) in plan view, and (b) in cross-section, layers of the security document being shown spaced apart for clarity.

The description below will focus on examples security print media used in the production of banknotes. However, as mentioned above, the security print media could be used to form any type of security document, including passports (or individual pages thereof), identification cards, certificates, cheques and the like. Throughout this disclosure, the term "security print media" is used synonymously with the term "document substrate", meaning a medium which can then be printed upon and otherwise processed to form the desired security document, in a manner analogous to the printing and subsequent processing of a conventional paper substrate (albeit with processes adapted for use on polymer). Hence a "security print medium" does not encompass graphics layers and the like, which are later printed onto the security print medium to provide security patterns, indicia, denomination identifiers, currency identifiers etc. The combination of such a graphics layer and a "security print medium" (and optionally additional features such as applied foils, strips, patches etc) is the "security document".

Throughout the following examples, the security print medium will be illustrated as having the same size and shape as a security document into which it is later formed. However, typically the security print medium will be formed as a web or sheet large enough to carry multiple repeats of the desired security document, and will then be cut into individual document either before, but more usually after, printing of the graphics layer and any other required processing steps.

Figure 1 shows a first embodiment of a security print medium 1. Figures 1(a) and 1(b) show the security print medium before the application of any opacifying layers, with Figure 1(a) showing a plan view of the security print medium, and Figure 1(b) showing a cross-section along the line X-X'. It will be appreciated that in Figure 1(b) the layers forming the security print medium 1 are shown spaced apart for clarity whereas in practice all of the layers will contact one another and form a cohesive unit. The same applies to all other cross-sections shown in other Figures.

As shown in Figures 1(a) and 1(b), the security print medium 1 comprises a polymer substrate 5, which is transparent (i.e. optically clear, but may be tinted) or translucent (i.e. optically scattering, but non-opaque). The polymer substrate 5 may be monolithic or could be multi-layered and may carry additional layers on its first and/or second surfaces 5a, 5b such as a primer layer for improving the adhesion of

outer layers. The polymeric substrate may comprise BOPP or polycarbonate, for example.

The polymer substrate 5 has opposing upper and lower surfaces 5a, 5b. In a region, on the upper surface 5a, there is disposed a multi-tonal image 10 (multi-tone second image) in the form of a single print working 10a (print of the multi-tone second image). In this example, the multi-tone image 10 is formed by a square shaped print working 10a which has a lighter tone towards its centre and a darker tone towards its perimeter to give the impression to the viewer that the centre is closer than the edges. The print working 10a may be formed by a conventional colour ink using a process such as gravure printing or flexographic printing. The ink may be selected so as to be translucent to allow the colour to be visible in transmitted light.

The print 10a can be applied using any available application technique. For example, the print 10a could be applied by gravure, flexographic, lithographic or any other available printing technique, or by applying an all-over layer of ink and then selectively removing parts of it to define an image, e.g. by laser ablation or etching.

As shown in Figure 1(c), substantially all of the medium 1 carries a coating 6 formed of a plurality of opacifying layers as described further below. This renders the medium non-transparent across the whole of the coated area and provides a suitable background for printing thereon. The coating 6 may optionally be omitted in certain areas of the medium to form features such as strip 2 and window 3, which are transparent or translucent (relative to the coated areas). Such transparent areas may be provided as security features in their own right or may be later equipped with additional security devices during the manufacture of a security document using the medium 1, as described further below. At least some of the opacifying layers forming coating 6 also have gaps in a region 8 of the medium, which are configured to form a multi-tone image 9 (multi-tone first image) as will be detailed below. Nonetheless, in preferred examples each opacifying layer covers at least 50% of the area of the security

The opacifying coating 6 can be applied on one or both surfaces 5a, 5b of the polymer substrate 5 and in this case comprises four opacifying layers 6a, 6c, 6e, 6g

on the upper surface 5a, and two opacifying layers 6b, 6d on the lower surface 5b. Each opacifying layer comprises a translucent, semi-opaque material which is preferably polymeric and non-fibrous, e.g. white ink. The opacifying layers are each preferably substantially the same colour as one another (and are spatially uniform in colour), most preferably white or another light colour such as off-white or grey so that a later-applied graphics layer will contrast well against it. In preferred examples, the opacifying layers each have a brightness L* in CIE L*a*b* colour space of at least 70, preferably at least 80 and more preferably at least 90.

In this example, on the upper side 5a of the substrate 5, three of the opacifying layers 6c, 6e, 6g contribute to the formation of multi-tone first image 9 whilst the fourth opacifying layer 6a is continuous across region 8 and hence does not contribute to the multi-tone first image other than to increase its optical density uniformly throughout. On the lower side of the substrate, two opacifying layers 6b, 6d extend substantially across the entire surface of the substrate, and completely cover the multi-tone first and second images from the point of view of an observer viewing the lower side of the substrate. It should be noted that the order in which the opacifying layers 6c, 6e, 6g are arranged and their location with respect to other opacifying layers on the upper side of the substrate is unimportant since it is their cumulative effect, when all are viewed in combination, which creates the desired image. These considerations apply to all embodiments.

Each of the opacifying layers 6c, 6e and 6g, which contribute to the formation of the multi-tone first image 9, includes a gap in the region 8 which is defined in accordance with a different respective sub-image. The sub-images are shown in plan view in Figures 2(a), (b) and (c) for layers 6c, 6e and 6g, respectively (each of Figures 2(a) to (c) showing only a section of the respective opacifying layer including and surrounding region 8, and omitting the remainder of the layer). The different sub-images are configured such that once the opacifying layers are arranged on top of one another, as shown in Figure 1(d), the cumulative effect of the different sub-images is a variation in the optical density of the security print medium across region 8 which appears as the multi-tone image 9 when viewed in reflected light.

Specifically, with each opacifying layer being white in colour, the innermost circular portion 9a has the lowest optical density (or tone), achieved by providing

corresponding gaps in all of the opacifying layers except for layer 6a such that a single opacifying layer is present across portion 9a, and therefore appears darkest in reflected light, and the outermost annular portion 9d has the highest optical density (or tone), achieved by providing gaps in none of the opacifying layers in this portion, such that all four are present here, thereby appearing lightest in tone in reflected light. Intermediate annular portions 9b and 9c are provided with respective intermediate optical density / tonal values, achieved by locating gaps in these portions in one of the four opacifying layers and in two of the four opacifying layers, respectively. Thus, taking the optical density of innermost portion 9a to be 0% on an arbitrary relative scale, and that of outermost portion 9d to be 100%, portion 9b has an optical density of 33% and portion 9c an optical density of 66%. Alternatively, on an absolute scale, if each opacifying layer 6a,c,e,g has an optical density of 0.2 (as measured on a transmission densitometer such as the MacBeth TD932, with an aperture area equivalent to that of a circle with a 1mm diameter), portion 9a will have an optical density of 0.2, portion 9b an optical density of 0.4, portion 9c an optical density of 0.6 and portion 9d an optical density of 0.8. These different optical densities appear as a variation in tone across the image, resulting in a three-dimensional effect.

As mentioned above, when the medium 1 is viewed in reflected light, particularly on a dark background, the innermost portion 9a will appear darkest since its low optical density reflects the least amount of incident light, whilst the outermost portion 9d will appear lightest due to its high optical density reflecting comparatively more light. As a result, the centre 9a of the multi-tonal image 9 will appear further from the viewer than the edges.

When the medium is switched to being viewed in transmitted light, (i.e. against a backlight), light passes through the security medium 1, and in particular, through the print working 10a of the multi-tonal second image 10 and through the opacifying layers 6a, 6c, 6e, 6g forming the multi-tonal first image 9. When the viewer looks in the region of the multi-tonal second image 10, which overlaps the region 8 of the multi-tonal first image 9, a bright central region is visible, corresponding to the lighter areas of the print working 10a of the multi-tonal second image 10, contrasted against a darker outer region, corresponding to the darker areas of the print working 10a of the multi-tonal second image 10. The modulation of light passing through the

security medium 1 by the print working 10a of the multi-tonal second image 10 dominates the appearance of security medium, overwhelming any visible modulation of light intensity resulting from the opacifying layers 6a, 6c, 6e, 6g.

The result of the above is a transition between a first multi-tonal image, visible in reflection, and a second multi-tonal image, different from the first, visible in transmission in at least an overlapping region on the substrate.

Referring now to Figure 2, the sub-images according to which each opacifying layer 6c, e, g is arranged will be described in more detail. The sub-image defined in opacifying layer 6g is shown in Figure 2(a) and it will be seen that this comprises a circular gap extending across the portions 9a,b,c of the multi-tone image, wholly surrounded by the opacifying material of layer 6g. The periphery of the circular gap therefore corresponds to the boundary between portion 9c and portion 9d in the multi-tone image 9. The opacifying material of layer 6g is present across portion 9d of the multi-tone image (the outer edge of which corresponds to the periphery of region 8, shown for reference). Hence the sub-image is defining portions of the desired multi-tone image according to their intended tone (or analogously their optical density): in this sub-image, portions of the multi-tone image having a desired tone of more than 66% up to and including 100% (in this case, portion 10d) are denoted by the presence of opacifying material whilst portions having a desired tone of 66% or less correspond to a gap in the layer.

Likewise, the sub-image defined in opacifying layer 6e (Figure 2(b)) defines portions of the desired multi-tone image according to a different, larger, tonal range: here, portions of the multi-tone image having a desired tone of more than 33% up to and including 100% (in this case, portions 9c and 9d) are denoted by the presence of opacifying material whilst portions having a desired tone of 33% or less correspond to a gap in the layer. Hence, the sub-image comprises a circular gap extending across portions 9a and 9b of the multi-tone image, its periphery lying on the boundary between portions 9b and 9c.

Finally, the sub-image defined in opacifying layer 6c (Figure 2(c)) defines portions of the desired multi-tone image according to a still larger tonal range: portions of the multi-tone image having a desired tone of more than 0% up to and including 100%

(in this case, portions 9c and 9d) are denoted by the presence of opacifying material whilst portions having a desired tone of 0% correspond to a gap in the layer. Hence, the sub-image comprises a circular gap extending across portion 9a only of the multi-tone image, its periphery lying on the boundary between portions 9a and 9b.

It will be noted that the size of the tonal range defined in each sub-image is different and that each range falls wholly within that of the next sub-image (if they are placed in sequence according to the size of their respective tonal ranges). One end point (100%) is the same for each tonal range whilst the other end value varies.

In the above example, all of the sub-images are binary or "flat" images meaning that the opacifying material is either present or absent across each part of the image (on a scale large enough to be appreciated by the naked eye), and there are no intermediate levels. This will be desirable in many cases, especially where a sharp "step-change" in tone is required in the final multi-tone image, e.g. to define a straight edge in the image of an object. If this is not desired, one option to achieve a more gradual change in tone from one portion of the image to the next would be to utilise a greater number of opacifying layers, possibly of lower individual optical density, and a corresponding number of sub-images, arranged so as to achieve a more closely-spaced series of smaller changes in tone. However, this may result in an undesirably thick construction of the security print medium 1 and would also require a corresponding increase in the number of processing steps.

Figures 3(a), (b) and (c) show alternative sub-images for each of the opacifying layers 6g, e, c respectively in the Figure 1 embodiment, which address this. The sub-image for each layer is substantially the same as in the Figure 2 example, defining portions of the multi-tone image according to their desired tone, based on the same different tonal range for each sub-image as previously described, but in this case each of the sub-images itself is multi-tonal, i.e. defining at least one intermediate tone beyond the binary options of "present" or "absent", on a scale visible to the naked eye. For example, each sub-image may be formed as a half tone image in which elements of the image are laid down with varying size and/or ink weight to give rise to the required variation in tone. In the present example, this multi-tonal nature of the sub-image is used to replace the sharp periphery of the gap in each opacifying layer with a boundary region in which the tone of the sub-image is

intermediate (e.g. 50% fill factor) or gradually increases from zero on the side of the gap to 100% on the other wise. This visually softens the edge of each opacifying layer resulting in a more gradual change between tones in the final multi-tone image.

In the present example, all of the sub-images are formed as multi-tone images in this way but this is not essential. In other cases, just one of the sub-images, or a sub-set of the sub-images, may be multi-tonal whilst the remaining one or more sub-images may be binary images.

Multi-tonal sub-images can also be used for purposes other than smoothing transitions between gaps and non-gap portions of a sub-image. More generally, the use of multiple tones in one or more of the sub-images allows for the creation of more complex multi-tonal images once the sub-images are combined since the number of available tones is no longer limited to the number of opacifying layers applied. Rather, by varying the tone across any of the individual sub-images and layering them with further sub-images as necessary, a much larger number of different tones can be created thereby allowing for the formation of a more complex multi-tone image.

It should be appreciated that this can be applied to all embodiments described below, in which any one or more of the described sub-images could be implemented as a multi-tonal sub-image to obtain the above-mentioned advantages.

A further optional but beneficial feature will now be described with reference to Figure 4. Figure 4(a) shows an exemplary raised pattern layer 13 which may be applied over the outermost opacifying layer(s) across the region 8 of the medium 1. For instance, in the Figure 1 embodiment, the raised pattern layer 13 may be applied over the opacifying layer 6g on the first surface of the substrate 5. The raised pattern layer may comprise for example a colourless, transparent ink which is applied to the medium 1 in accordance with a screen pattern, the elements of which are large enough to be individual discernible to the naked eye (possibly only under close inspection). For example, the raised pattern layer 13 may be applied in the form of an array of line or dot screen elements. In this case, the raised pattern layer is in the form of a grid of lines as shown. The raised pattern layer may be applied by

intaglio printing for example and preferably has a latent appearance in that its presence is less visible when the medium is viewed at some angles, relative to others. At certain viewing angles, which depend on the location of the illuminating light source, the raised image pattern will reflect light more strongly to the viewer, and thus become more visible, than at other viewing angles. The pattern 13 may or may not be directly related to the content of either of the multi-tone images 9, 10, but in particularly preferable embodiments, the pattern 13 is related to the multi-tonal image 9 seen in reflection and produced by the opacifying layers. In this example, the raised pattern layer extends across the same region 8, matching the outline of the multi-tone first image, but otherwise does not reflect the features of the multi-tone first image 9, instead comprising a grid pattern, the line weight of which varies from left to right across the region such that it fades to absent on the right side of the region 8. Preferably the raised pattern layer is tactile (i.e. can be detected by human touch), but this is not essential.

A raised pattern layer of the sort described above can be used on its own to add complexity to the multi-tone image feature. However it is preferred to integrate the pattern with the multi-tone image by arranging one of the opacifying layers 6 in accordance with a similar screened pattern.

In previous embodiments, each opacifying layer 6a to 6g has been laid down in a substantially homogenous manner so as to uniformly cover the desired portions of the substrate 5, at least on a macroscopic scale which is visible to the naked eye. In practice such layers may be formed by gravure printing for example, which involves applying the opacifying material from an array of cells, the size of which is typically too small for any resulting pattern structure to be visible to the naked eye.

However in the present example, one or more of the opacifying layers is formed in accordance with an array of screen elements, such as dots or lines, which are sufficiently large that the screen structure is visible to the naked eye. An example of such an opacifying layer 6a' is shown in Figure 6(b). This could be provided in place of layer 6a or as an additional layer, for example, applied over the top of the uppermost opacifying layer 6g. In this example, the opacifying material of this layer which extends across the region 8, i.e. covering portions 9a to d of the multi-tone image, is now applied in accordance with a screen of dots arranged on an

orthogonal grid. The size of the dot elements varies across the region from small on the left side to large on the right side. This results in a small-scale structure to the tones visible in the multi-tone pattern which interacts with that of the raised pattern layer 13. The two screen patterns are selected to be of similar sizes and element shapes, that of raised pattern layer 13 being dominant on the left hand side of the region 8, and that that of opacifying layer 6a' being dominant on the right hand side.

Figure 5 shows a second embodiment of the invention formed based on the same principles as described in relation to the first embodiment, i.e. that shown in Figure 1. The construction of the security print medium 1 is largely the same as previously described, common components being denoted in the Figures using the same reference numerals as used above.

In this embodiment, the multi-tonal second image 10 is formed by a print working 10a applied to the entire upper surface 5a of the substrate 5. In this embodiment, the print of the multi-tonal second image 10 is a monochromatic picture of a flower. The print working 10a is formed of a translucent blue ink applied as a half-tone print working in accordance with the multi-tonal second image 10.

Applied over the print of the multi-tonal second image 10 are a first, continuous opacifying layer 6a extending over the entire upper surface 5a of the substrate 5, and three opacifying layers 6c, 6e, 6g applied in that order, each opacifying layer 6c, 6e, 6g being formed in accordance with a respective sub-image and each extending over substantially the entire upper surface 5a of the substrate 5. It should be appreciated that whilst in practice the opacifying layers will typically be white, here the opacifying material is illustrated as black in order to be visible in the Figure. Thus the white portions surrounded by black in fact correspond to gaps in the opacifying layers, and the black portions represent the areas where opacifying material is present.

Applied to the lower surface 5b of the substrate 5 are two opacifying layers 6b, 6d, applied in that order, each extending continuously over substantially the entire lower surface of the substrate.

Collectively, the opacifying layers 6c, 6e, 6g, applied in accordance with a respective sub-image, define the multi-tonal first image 9 in a region 8, the region 8 corresponding to a central band stretching longitudinally along the substrate. The multi-tonal first image 9, defined by the sub-images, in this embodiment is a complex repeating pattern.

When the upper surface 5a of the substrate 5 is viewed in reflection, the pattern, which is the multi-tonal first image 9 formed by the opacifying layers 6c, 6e, 6g, is visible across the centre of the substrate 5. When the media 1 is switched to being viewed in transmission, the multi-tonal second image 10, formed by the print working 10a, becomes visible across the entire surface of the note, and dominates the appearance of the media 1.

The multi-tonal first image 9, from which the sub-images are derived, in this example is a pattern, and the opacifying layers 6c, 6e, 6g include gaps which, in at least some places, align over the print working 10a. Opacifying layer 6a is provided substantially continuously across the substrate and will typically hide the print working 10a in reflection, even in the places where the gaps in opacifying layers 6c, 6e, 6g align. While the continuous opacifying layer 6a will typically hide all of the print working 10a in reflection, the opacifying layer 6a could alternatively be configured so as to have a very low opacity, e.g. an opacity of approximately 0.05 or less (i.e. substantially zero), so that the print of the multi-tonal second image 10 is visible when the medium is viewed in reflection, through the aligned gaps in the opacifying layers 6c, 6e, 6g. While the print of the second image is visible in reflection through the gaps in the opacifying layers 6c, 6e, 6g, the second image as a whole remains unidentifiable in reflection since the image is obscured at frequent intervals across the surface of the medium by opacifying material having an opacity greater than substantially zero (i.e. an opacity of 0.05 or greater in places where one or more of layers 6c, 6e and 6g are present). If small regions of the print 10a are visible in reflection, (i.e. if there are points at which the opacifying coating has an opacity of substantially zero) this may enhance the appearance of the first image 9 (e.g. by providing one or more background colours) without revealing the second image in reflection.

In reflection, the visibility of the second print at any one point on the surface of the substrate 5 will depend on the total opacity of the opacifying layers 6a, 6c, 6e, 6g in combination. The print 10a will be most visible (if at all) where a gap is present in all of the opacifying layers formed as sub-images 6c, 6e, 6g as it will only be the continuous opacifying layer 6a which acts to obscure the print. The print 10a will be less visible (typically substantially not visible) at points over which two opacifying layers 6e, 6g have gaps, as now the continuous opacifying layer 6a and a first opacifying layer 6c formed in accordance with a sub-image will act to obscure the print 10a. Visibility will decrease again for points over which only one opacifying layer has gaps, and the print 10a will be least visible at points at which all of the opacifying layers 6a, 6c, 6e, 6g are present.

Figure 6 shows a third embodiment of the invention formed based on the same principles as described in relation to the first and second embodiments. The construction of the security print medium 1 is largely the same as the second embodiment in particular.

In this embodiment, the multi-tonal second image 10 is a multi-coloured, multi-tonal image, and is formed by four print workings 10a, 10b, 10c, 10d applied over one another on the upper surface 5a of the substrate 5. As in the second embodiment, the multi-tonal second image is an image of a flower, and extends across the entire upper surface 5a of the substrate 5. Each print working 10a, 10b, 10c, 10d is a halftone image in a different component colour, e.g. print working 10a is in yellow, print working 10b is in magenta, print working 10c is in cyan, and print working 10d is in black, which together form a multi-colour, multi-tonal image. While yellow, cyan, magenta and black are used in this embodiment, many combinations of print workings may be used to achieve different appearances of the multi-tonal image. In another example, a second working could be in a different colour to a first, and configured to provide different elements of the multi-tone image – e.g. the first working could be provided only in a first half on the image and the second working in a second half to provide two halves in different colours – or could overlap with the first to provide an intermediate colour such as orange where the first working is red and the second yellow. Alternatively still, one or more of the workings 10a, 10b, 10c, 10d could be identical and in the same colour, to increase the intensity of that colour. While all workings 10a, 10b, 10c, 10d are applied to the upper surface of the

substrate, one or more could, instead, be disposed on the lower surface of the substrate and still contribute to the multi-tonal second image.

Over the multi-tonal second image on the upper surface 5a of the substrate 5 are three opacifying layers 6a, 6c, 6e, applied in that order, each formed in accordance with a respective sub-image and each extending over substantially the entire upper surface 5a of the substrate 5. As in the second embodiment, these opacifying layers collectively form a pattern, which is the multi-tonal first image 9, in a region 8, the region 8 corresponding to a central band stretching longitudinally along the substrate.

Similarly, on the lower surface 5b of the substrate 5 are disposed three opacifying layers 6b, 6d, 6f, applied in that order, each formed in accordance with a respective sub-image and each extending over substantially the entire lower surface of the substrate 5. In this embodiment, the opacifying layers 6b, 6d, 6f on the lower surface form a second multi-tonal first image 9'. In this case, the sub-image of the layer 6b corresponds to that of the layer 6a, the sub-image of the layer 6d corresponds to that of layer 6c, and the sub-image of the layer 6f corresponds to that of layer 6e such that the second multi-tonal first image 9', seen when the lower surface 5b is viewed in reflection, is identical to the multi-tonal first image 9 formed by the opacifying layers 6a, 6c, 6e.

In this embodiment, as there are points across both surfaces of the medium at which no opacifying material is present (i.e. where the gaps through either the upper opacifying layers 6a, 6c, 6e or lower opacifying layers 6b, 6d, 6f align), small regions of the print will be visible when the medium is viewed in reflection on either side, at those points where the gaps through the opacifying layers align, thereby enhancing the appearance of the first image in reflection. While portions of the print are visible, the second image as a whole remains unidentifiable in reflection since the image is obscured at frequent intervals across the surface of the medium by opacifying material where one or more of layers 6a, 6c, 6e or 6b, 6d, 6f are present, with the visibility of the print at any one point depending on the total opacity of the opacifying layers in combination. Typically, the print will be substantially not visible at points where it is covered by at least one opacifying layer.

In all of the above embodiments, it is preferred that each opacifying layer has an optical density in the range 0.1 to 0.5 (as measured on a transmission densitometer such as the MacBeth TD932, with an aperture area equivalent to that of a circle with a 1mm diameter), more preferably 0.1 to 0.3. Advantageously, the opacifying layers each have a brightness L* in CIE L*a*b* colour space of at least 70, preferably at least 80 and more preferably at least 90. Preferably, the opacifying layers should be white, off-white or grey. The composition of each opacifying layer may be the same or different to one another. In preferred examples, one of the opacifying layers on each side of the substrate may comprise electrically conductive particles to reduce the effect of static charge. Preferably this is the penultimate layer on each side.

The opacifying coating for any of the above embodiments will typically comprise a resin such as a polyurethane based resin, polyester based resin or an epoxy based resin and an opacifying pigment such as titanium dioxide (TiO2), silica, zinc oxide, tin oxide, clays or calcium carbonate.

The opacifying layers can each be applied by any suitable application process which allows their selective application in accordance with the respective sub-images. Typically, each opacifying layer will be applied by gravure printing. Alternatively, any of flexographic printing, screen printing or lithographic printing may be used. The opacifying layers and any print workings should preferably be applied in register with one another, as may be achieved by applying all of them in the same in-line process. As already mentioned, additional layers such as a primer could be applied to the substrate before the opacifying layers (and any optional print workings). Further layers could be applied to the outside of the opacifying layers, such as a protective layer (preferably transparent) or a print-receptive coating.

The above-described security print media can then be processed into security documents. The processing steps involved in doing so may be carried out on a separate processing line, typically at a different manufacturing site and optionally by a different entity. An example of a security document 100 formed using the security print medium 1 described above in relation to Figure 1 is shown in Figure 7, (a) in plan view and (b) in cross-section. All of the components already provided as part of the security print medium 1, including multi-tone first image 9 and multi-tone

second image 10, are as previously described in relation to Figure 1 and hence will not be described again.

The security document comprises a graphics layer 20 applied in this example to the outer surfaces of the security print medium 1, i.e. to the surface of outermost opacifying layers. In other cases the graphics layer 20 may be applied only to one or other of the surfaces. As mentioned previously there could be intermediate layers between the opacifying layers and the graphics layer, such as a protective layer or primer. In this example, the security document is a banknote and hence the graphics layer comprises background security patterns 20a (such as guilloches) as well as identifiers such as denomination information 20b. The graphics layer 20 could be applied in a single working or in multiple workings, optionally using more than one printing technique. Any available printing techniques can be utilised for forming the graphics layer as would be applied to a conventional polymer document substrate, e.g. intaglio printing, gravure printing, flexographic printing, lithographic printing etc.

Figure 7 also illustrates examples of other security devices which may optionally be applied to the security print media to form the security document, such as an optically variable device 21 in window 3, e.g. a moiré magnification device, a lenticular device or an integral imaging device as may be formed by cast-curing or laminating a lens array on one side of the polymer substrate 5 and forming image elements on the other. Also depicted is a security device 22 in the form of a patch which has been applied to the surface of the security print media, e.g. by lamination or hot stamping. The security device 22 may comprise a diffractive optical element such as a hologram, for example.

The security documents and security devices of the current invention can optionally be made machine readable by the introduction of detectable materials in any of the layers or by the introduction of separate machine-readable layers. Detectable materials that react to an external stimulus include but are not limited to fluorescent, phosphorescent, infrared absorbing, thermochromic, photochromic, magnetic, electrochromic, conductive and piezochromic materials.

CLAIMS

1. A security print medium for forming security documents therefrom, comprising a transparent or translucent polymer substrate having first and second opposing surfaces, and a plurality of overlapping opacifying layers disposed on the first and/or second surfaces of the polymer substrate, each of the opacifying layers being a layer of semi-opaque material, wherein in a first region of the substrate a multi-tonal first image is exhibited by the plurality of overlapping opacifying layers in combination with one another, each of the plurality of overlapping opacifying layers having gap(s) in which the semi-opaque material of the layer is absent, the gap(s) of each layer being defined in accordance with a different respective sub-image, the sub-images in combination defining the multi-tonal first image, whereby the number of opacifying layers overlapping one another at any one location varies across the substrate, the resulting variation in optical density of the plurality of overlapping opacifying layers in combination with one another giving rise to the multiple tones of the multi-tonal first image, and the security print medium further comprising a print of a multi-tonal second image, different from the first image, on the first and/or second surfaces of the polymer substrate in a second region and covered from the point of view of an observer on a first side of the security print medium by the plurality of opacifying layers exhibiting the multi-tonal first image, the first and second regions at least partially overlapping, whereby when the security print medium is viewed by the observer in reflected light, the first image dominates the appearance of the overlapping area(s) of the first and second regions and when the security print medium is viewed by the observer in transmitted light, the second image dominates the appearance of the overlapping area(s) of the first and second regions.

2. A security print medium according to claim 1, wherein the print of the multi-tonal second image is a multi-coloured print, preferably comprising multiple print workings, and preferably comprising multiple print workings in different colours.

3. A security print medium according to claim 1 or 2, wherein the print of the multi-tonal second image comprises at least one halftone print working.

4. A security print medium according to any of the preceding claims, further comprising one or more opacifying layers disposed continuously across the print of the multi-tonal second image so as to cover the print of the multi-tonal second image

from the point of view of an observer on the second side of the security print medium.

5. A security print medium according to any of the preceding claims, wherein each sub-image defines portions of the multi-tonal first image which have a tonal value falling within a respective tonal value range, the size of each respective tonal value range being different.

6. A security print medium according to claim 5, wherein when the tonal value ranges of the sub-images are ordered according to increasing size, each tonal value range falls within the tonal value range next in the sequence.

7. A security print medium according to claim 6, wherein all of the tonal value ranges share substantially the same first end value and differ in their second end values.

8. A security print medium according to any of the preceding claims, wherein at least some of the sub-images are multi-tonal sub-images, preferably half-tone sub-images.

9. A security print medium according to any of the preceding claims, wherein all of the opacifying layers are substantially the same colour as one another, preferably white or grey.

10. A security print medium according to any of the preceding claims, wherein the sub-images are configured such that a smaller number of the opacifying layers overlap one another at locations across the substrate corresponding to darker tones in the multi-tonal first image as seen in reflected light, relative to the number of opacifying layers which overlap one another at locations corresponding to lighter tones in the multi-tonal first image as seen in reflected light.

11. A security print medium according to any of the preceding claims, wherein the plurality of overlapping opacifying layers includes at least three overlapping opacifying layers each having gap(s) defined in accordance with a different respective sub-image.

12. A security print medium according to any of the preceding claims, further comprising one or more additional opacifying layers each comprising a layer of semi-opaque material disposed over substantially the whole area of the first and/or second region, the one or more additional opacifying layers each extending continuously across the first and/or second region.

13. A security print medium according to any of the preceding claims, further comprising one or more additional opacifying layers each comprising a layer of semi-opaque material disposed over substantially the whole area of the polymer substrate, the one or more additional opacifying layers each either extending continuously across the first and/or second region or comprising a gap substantially across the first and/or second region.

14. A security print medium according to any of the preceding claims, wherein when the security print medium is viewed by the observer in reflected light, the print of the second image is at least partly visible in area(s) corresponding to gap(s) in at least one of the plurality of opacifying layers in the overlapping area(s) of the first and second regions.

15. A security print medium according to any of the preceding claims, wherein when the security print medium is viewed by the observer in reflected light, the print of the second image contributes a background to the first image in the overlapping area(s) of the first and second regions.

16. A security print medium according to any of the preceding claims, wherein when the security print medium is viewed by the observer in reflected light, the colour of the print of the second image is visible in the overlapping area(s) of the first and second regions.

17. A security print medium according to any of the preceding claims, wherein the opacifying layers in combination have an optical density of at least 0.4 over at most 50%, preferably at most 30%, more preferably at most 20%, of the overlapping area(s) of the first and second regions.

18. A security print medium according to any of the preceding claims, wherein the opacifying layers in combination have an optical density greater than

substantially zero over at least 50%, preferably at least 70%, more preferably at least 80% of the overlapping area(s) of the first and second regions.

19. A security print medium according to any of the preceding claims, wherein the opacifying layers in combination have an optical density of substantially zero over one or more part(s) of the overlapping area(s) of the first and second regions.

20. A security print medium according to any of the preceding claims, further comprising at least one transparent window region formed by aligned gaps in each of the opacifying layers, the at least one transparent window region preferably substantially surrounding the multi-tonal first and second images.

21. A security print medium according to any of the preceding claims, wherein at least one of the sub-images is formed of an array of screen elements which are sufficiently large to be individually discernible to the naked eye, the size of the screen elements varying across the array to define the sub-image.

22. A security print medium according to any of the preceding claims, further comprising a raised pattern layer applied to the outermost opacifying layer on one or both sides of the substrate, the raised pattern layer comprising an array of screen elements which are sufficiently large to be individually discernible to the naked eye, the raised pattern layer preferably being tactile and/or of varying visibility depending on the viewing angle.

23. A security print medium according to claims 21 and 22, wherein the array of screen elements forming the at least one of the sub-images is arranged to visually cooperate with the array of screen elements forming the raised pattern layer.

24. A security print medium according to any of the preceding claims, wherein the opacifying layers are printed opacifying layers, preferably applied to the substrate by gravure printing.

25. A security print medium according to any of the preceding claims, wherein at least some of the opacifying layers are applied in the form of an array of screen elements which are too small to be individually discernible to the naked eye.

26. A security print medium according to any of the preceding claims, wherein at least one of the opacifying layers comprises electrically conductive particles.

27. A security print medium according to any of the preceding claims, wherein the multi-tonal first image and/or the multi-tonal second image comprises an image of a three-dimensional object, preferably a geometrical solid or wireframe model, a person, an animal, a building or other architectural structure or a three-dimensional logo.

28. A security print medium according to any of the preceding claims, wherein one of the first region and the second region is substantially the entire first and/or second surface of the substrate.

29. A security print medium according to any of the preceding claims, wherein one of the first region and the second region is contained completely within the other of the first and second region.

30. A security print medium according to any of the preceding claims, wherein the first region and the second region are substantially the same.

31. A security print medium according to any of the preceding claims, wherein the plurality of opacifying layers are disposed across at least 50% of the substrate, preferably at least 80% of the substrate, more preferably all of the substrate outside of the first region.

32. A security document comprising a security print medium according to any of claims 1 to 31, and at least one graphics layer applied on the outermost opacifying layer(s) on the first and/or second surfaces of the polymer substrate.

33. A security document according to claim 32, wherein the security document is a bank note, an identification document, a passport, a licence, a cheque, a visa, a stamp or a certificate.

34. A method of making a security print medium, comprising:

providing a transparent or translucent polymer substrate having first and second opposing surfaces;

applying a print of a multi-tonal second image on the first and/or second surfaces of the polymer substrate in a second region;

applying a plurality of overlapping opacifying layers onto the first and/or second surfaces of the polymer substrate, each of the opacifying layers being a layer of semi-opaque material, wherein in a first region of the substrate a multi-tonal first image is exhibited by the plurality of overlapping opacifying layers in combination with one another, each of the plurality of overlapping opacifying layers having gap(s) in which the semi-opaque material of the layer is absent, the gap(s) of each layer being defined in accordance with a different respective sub-image, the sub-images in combination defining the multi-tonal first image, whereby the number of opacifying layers overlapping one another at any one location varies across the substrate, the resulting variation in optical density of the plurality of overlapping opacifying layers in combination with one another giving rise to the multiple tones of the multi-tonal first image;

wherein the plurality of overlapping opacifying layers cover the multi-tonal second image from the point of view of an observer on a first side of the security print medium, and the first and second regions at least partially overlap;

whereby when the security print medium is viewed by the observer in reflected light, the first image dominates the appearance of the overlapping area(s) of the first and second regions and when the security print medium is viewed by the observer in transmitted light, the second image dominates the appearance of the overlapping area(s) of the first and second regions.

35. A method of making a security print according to claim 34, wherein the print of the multi-tonal second image is a multi-coloured print, and wherein preferably the step of applying the print of the multi-tonal second image comprises the steps of applying a first working onto the first and/or second surface of the polymer substrate and applying a second working onto the first and/or second surface of the polymer substrate, and wherein preferably the first and second workings are in different colours.

36. A method of making a security print according to claim 34 or claim 35, wherein the print of the multi-tonal second image comprises at least one halftone print working.

37. A method of making a security print according to any of claims 34 to 36, wherein applying a plurality of overlapping opacifying layers further includes

applying one or more opacifying layers continuously across the print of the multi-tonal second image so as to cover the print of the multi-tonal second image from the point of view of an observer on the second side of the security print medium.

38. A method of making a security print according to any of claims 34 to 37, wherein each sub-image defines portions of the multi-tonal first image which have a tonal value falling within a respective tonal value range, the size of each respective tonal value range being different.

39. A method of making a security print according to claim 38, wherein when the tonal value ranges of the sub-images are ordered according to increasing size, each tonal value range falls within the tonal value range next in the sequence.

40. A method of making a security print according to claim 39, wherein all of the tonal value ranges share substantially the same first end value and differ in their second end values.

41. A method of making a security print according to any of claims 34 to 40, wherein at least some of the sub-images are multi-tonal sub-images, preferably half-tone sub-images.

42. A method of making a security print according to any of claims 34 to 41, wherein all of the opacifying layers are substantially the same colour as one another, preferably white or grey.

43. A method of making a security print according to any of claims 34 to 42, wherein the sub-images are configured such that a smaller number of the opacifying layers overlap one another at locations across the substrate corresponding to darker tones in the multi-tonal first image as seen in reflected light, relative to the number of opacifying layers which overlap one another at locations corresponding to lighter tones in the multi-tonal first image as seen in reflected light.

44. A method of making a security print according to any of claims 34 to 43, wherein the plurality of overlapping opacifying layers includes at least three overlapping opacifying layers each having gap(s) defined in accordance with a different respective sub-image.

45. A method of making a security print according to any of claims 34 to 44, wherein applying a plurality of overlapping opacifying layers further includes applying one or more additional opacifying layers each comprising a layer of semi-opaque material disposed over substantially the whole area of the first and/or second region, the one or more additional opacifying layers each extending continuously across the first and/or second region.

46. A method of making a security print according to any of claims 34 to 45, wherein applying a plurality of overlapping opacifying layers further includes applying one or more additional opacifying layers each comprising a layer of semi-opaque material disposed over substantially the whole area of the polymer substrate, the one or more additional opacifying layers each either extending continuously across the region of the substrate containing the multi-tonal first and second images or comprising a gap substantially across the first and/or second region.

47. A method of making a security print according to any of claims 34 to 46, wherein when the security print medium is viewed by the observer in reflected light, the print of the second image is at least partly visible in area(s) corresponding to gap(s) in at least one of the plurality of opacifying layers in the overlapping area(s) of the first and second regions.

48. A method of making a security print according to any of claims 34 to 47, wherein when the security print medium is viewed by the observer in reflected light, the print of the second image contributes a background to the first image in the overlapping area(s) of the first and second regions.

49. A method of making a security print according to any of claims 34 to 48, wherein when the security print medium is viewed by the observer in reflected light, the colour of the print of the second image is visible in the overlapping area(s) of the first and second regions.

50. A method of making a security print according to any of claims 34 to 49, wherein the opacifying layers in combination have an optical density of at least 0.4 over less than 50%, preferably less than 30%, more preferably less than 20%, of the overlapping area(s) of the first and second regions.

51. A method of making a security print according to any of claims 34 to 50, wherein the opacifying layers in combination have an optical density greater than substantially zero over at least 50%, preferably at least 70%, more preferably at least 80% of the overlapping area(s) of the first and second regions.

52. A method of making a security print according to any of claims 34 to 51, wherein the opacifying layers in combination have an optical density of substantially zero over one or more part(s) of the overlapping area(s) of the first and second regions.

53. A method of making a security print according to any of claims 34 to 52, wherein the plurality of opacifying layers are applied such that gaps in each of them align to form at least one transparent window region, the at least one transparent window region preferably substantially surrounding the multi-tonal first and/or second images.

54. A method of making a security print according to any of claims 34 to 53, wherein at least one of the opacifying layers is applied in the form of an array of screen elements defining the respective sub-image, the screen elements being are sufficiently large to be individually discernible to the naked eye, the size of the screen elements varying across the array to define the sub-image.

55. A method of making a security print according to any of claims 34 to 54, further comprising applying a raised pattern layer to the outermost opacifying layer on one or both sides of the substrate, the raised pattern layer comprising an array of screen elements which are sufficiently large to be individually discernible to the naked eye, the raised pattern layer preferably being tactile and/or of varying visibility depending on the viewing angle.

56. A method of making a security print according to any of claims 34 to 55, wherein the array of screen elements forming the at least one of the sub-images is arranged to visually cooperate with the array of screen elements forming the raised pattern layer.

57. A method of making a security print according to any of claims 34 to 56, wherein the opacifying layers are applied by printing, preferably by gravure printing.

58. A method of making a security print according to any of claims 34 to 57, wherein at least some of the opacifying layers are applied in the form of an array of screen elements which are too small to be individually discernible to the naked eye.

59. A method of making a security print according to any of claims 34 to 58, wherein at least one of the opacifying layers comprises electrically conductive particles.

60. A method of making a security print according to any of claims 34 to 59, wherein the multi-tonal first image and/or the multi-tonal second image comprises an image of a three-dimensional object, preferably a geometrical solid or wireframe model, a person, an animal, a building or other architectural structure or a three-dimensional logo.

61. A method of making a security print according to any of claims 34 to 60, wherein one of the first region and the second region is substantially the entire first and/or second surface of the substrate.

62. A method of making a security print according to any of claims 34 to 61, wherein one of the first region and the second region is contained completely within the other of the first and second region.

63. A method of making a security print according to any of claims 34 to 62, wherein the first region and the second region are substantially the same.

64. A method of making a security print according to any of claims 34 to 63, wherein applying the plurality of opacifying layers onto the first and/or second surfaces of the polymer substrate comprises applying the plurality of opacifying layers across at least 50% of the substrate, preferably at least 80% of the substrate, more preferably all of the substrate outside of the first region.

65. A method of making a security document comprising:

making a security print medium in accordance with the method of any of claims 34 to 63; and

applying at least one graphics layer to the outermost opacifying layer(s) on the first and/or second surfaces of the polymer substrate.

66. A method of making a security document according to claim 65, wherein the security document is a bank note, an identification document, a passport, a licence, a cheque, a visa, a stamp or a certificate.

Fig. 1(a)

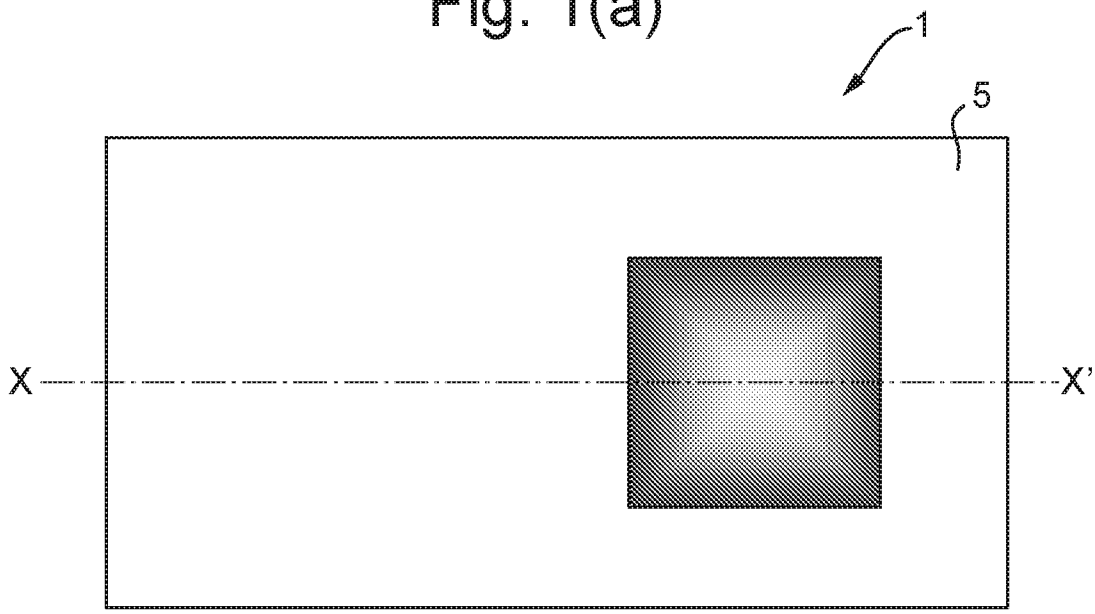


Fig. 1(b)

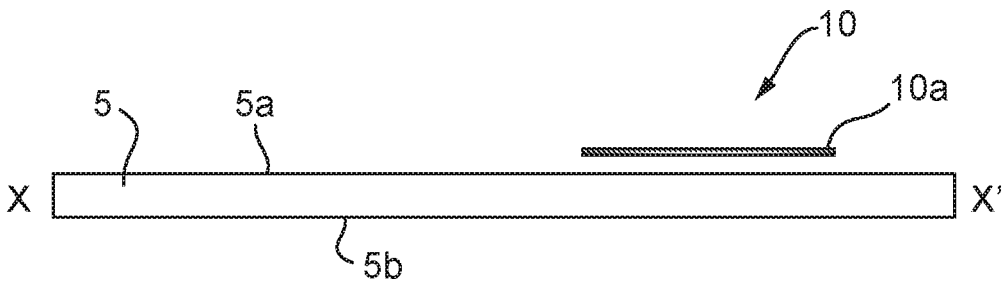


Fig. 1(c)

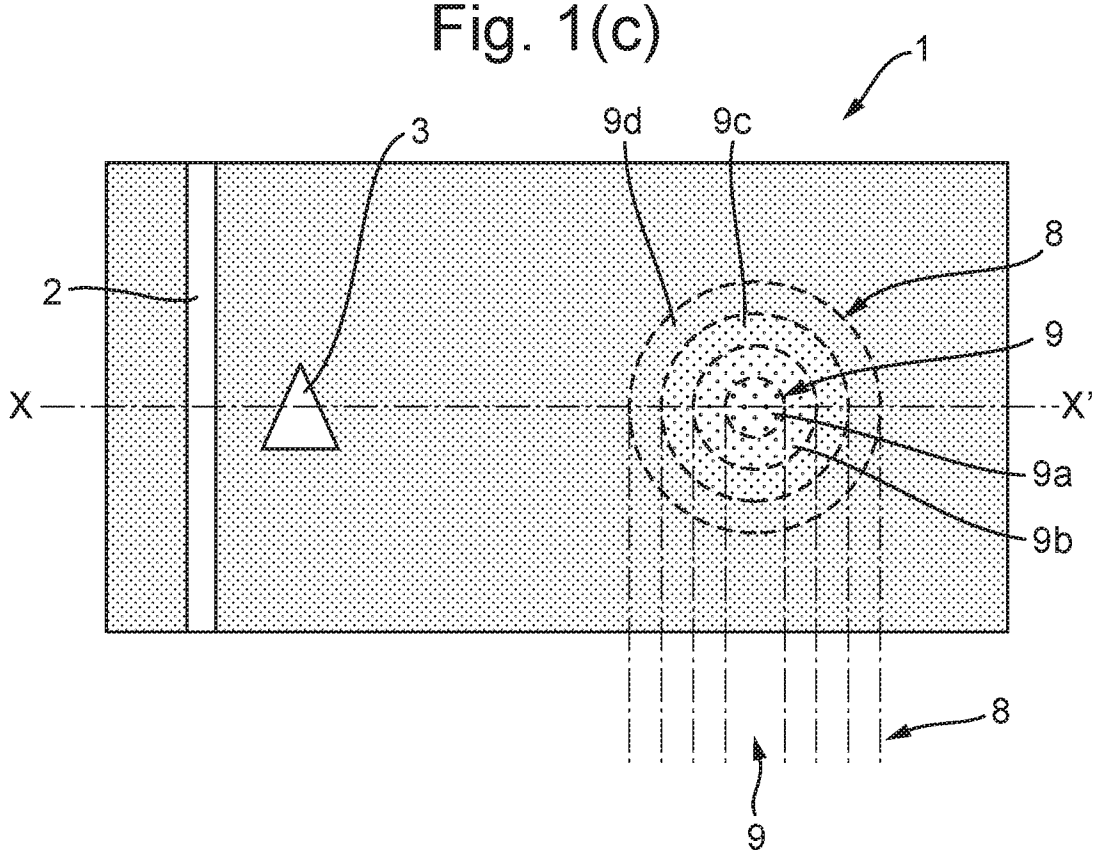


Fig. 1(d)

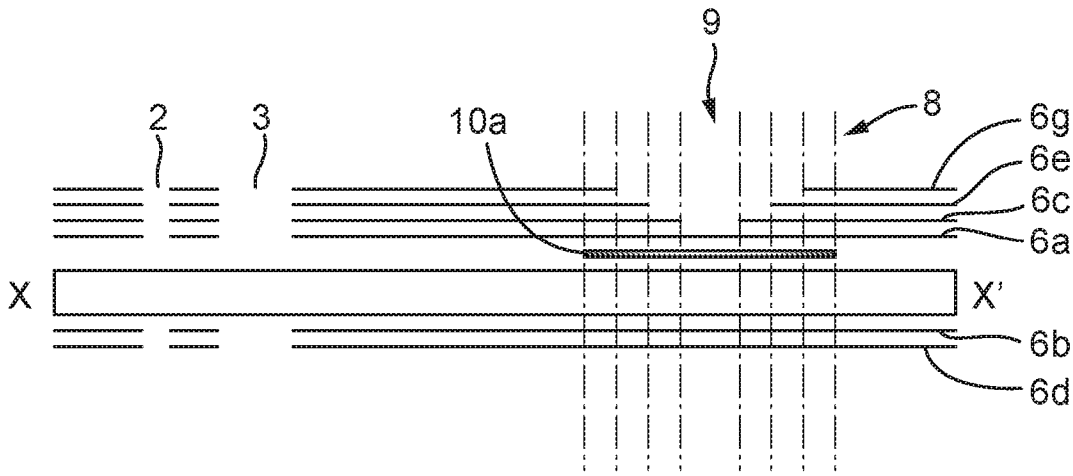


Fig. 2(a)

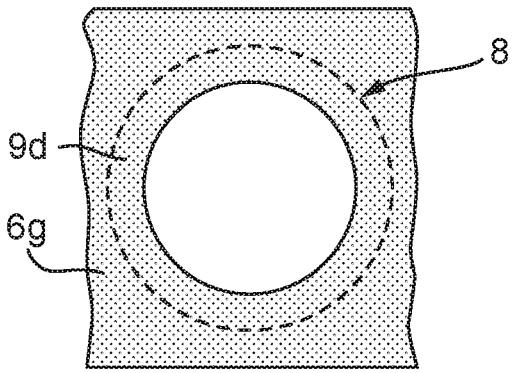


Fig. 3(a)

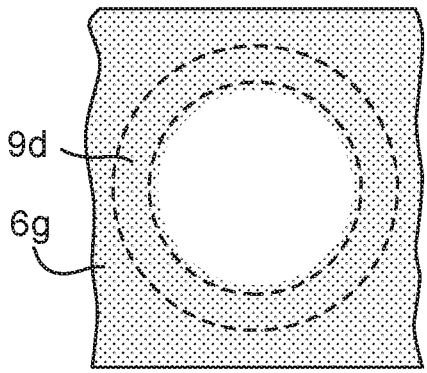


Fig. 2(b)

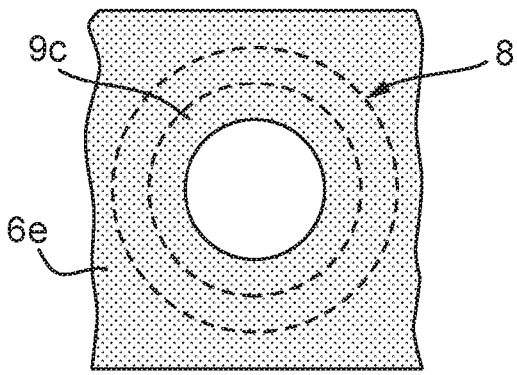


Fig. 3(b)

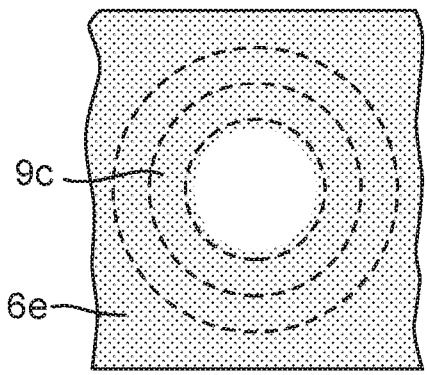


Fig. 2(c)

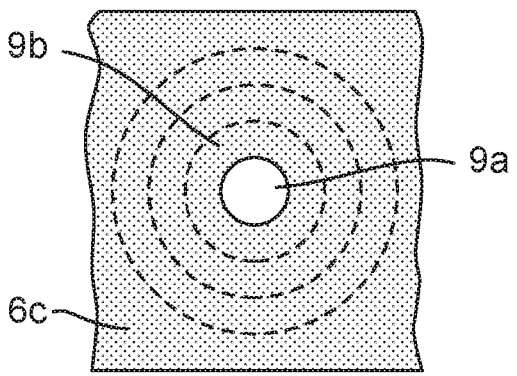


Fig. 3(c)

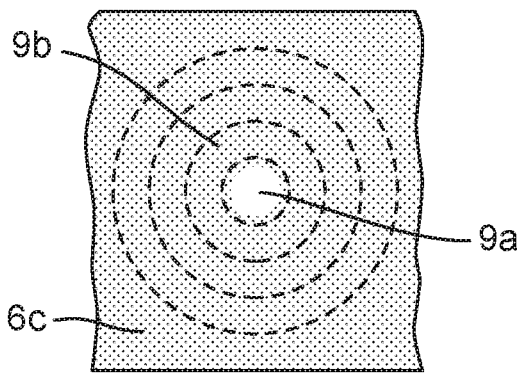


Fig. 4(a)

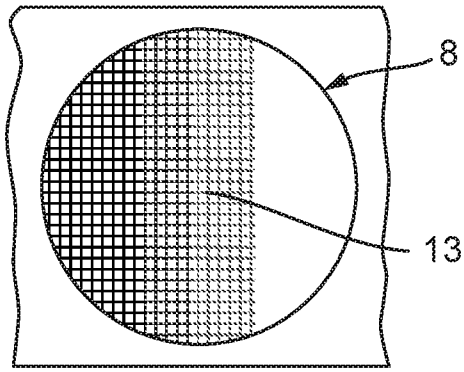


Fig. 4(b)

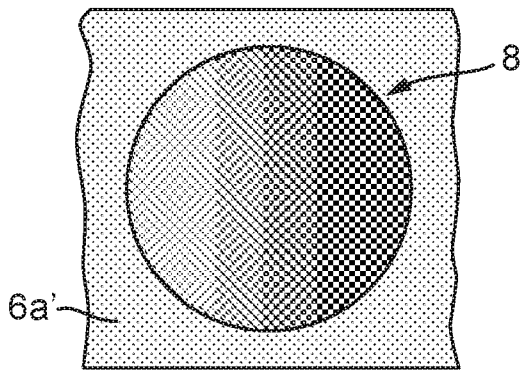


Fig. 5

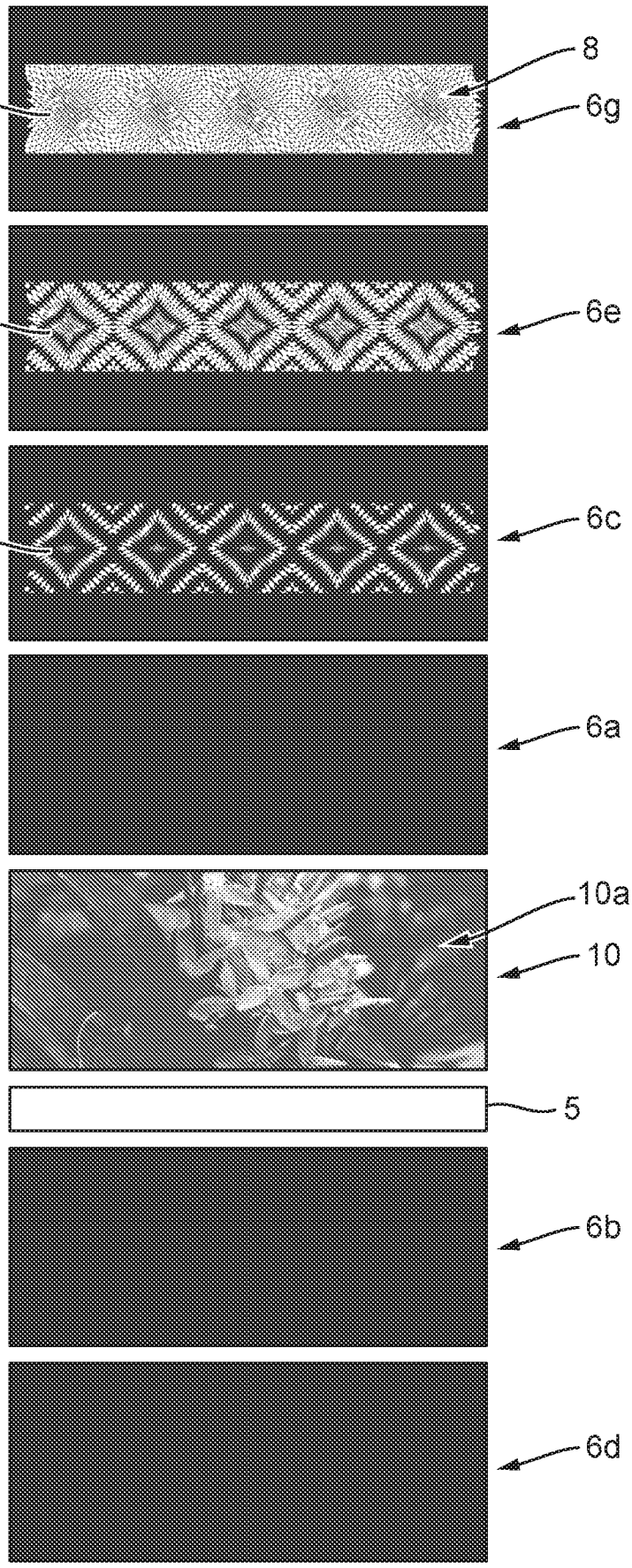


Fig. 6

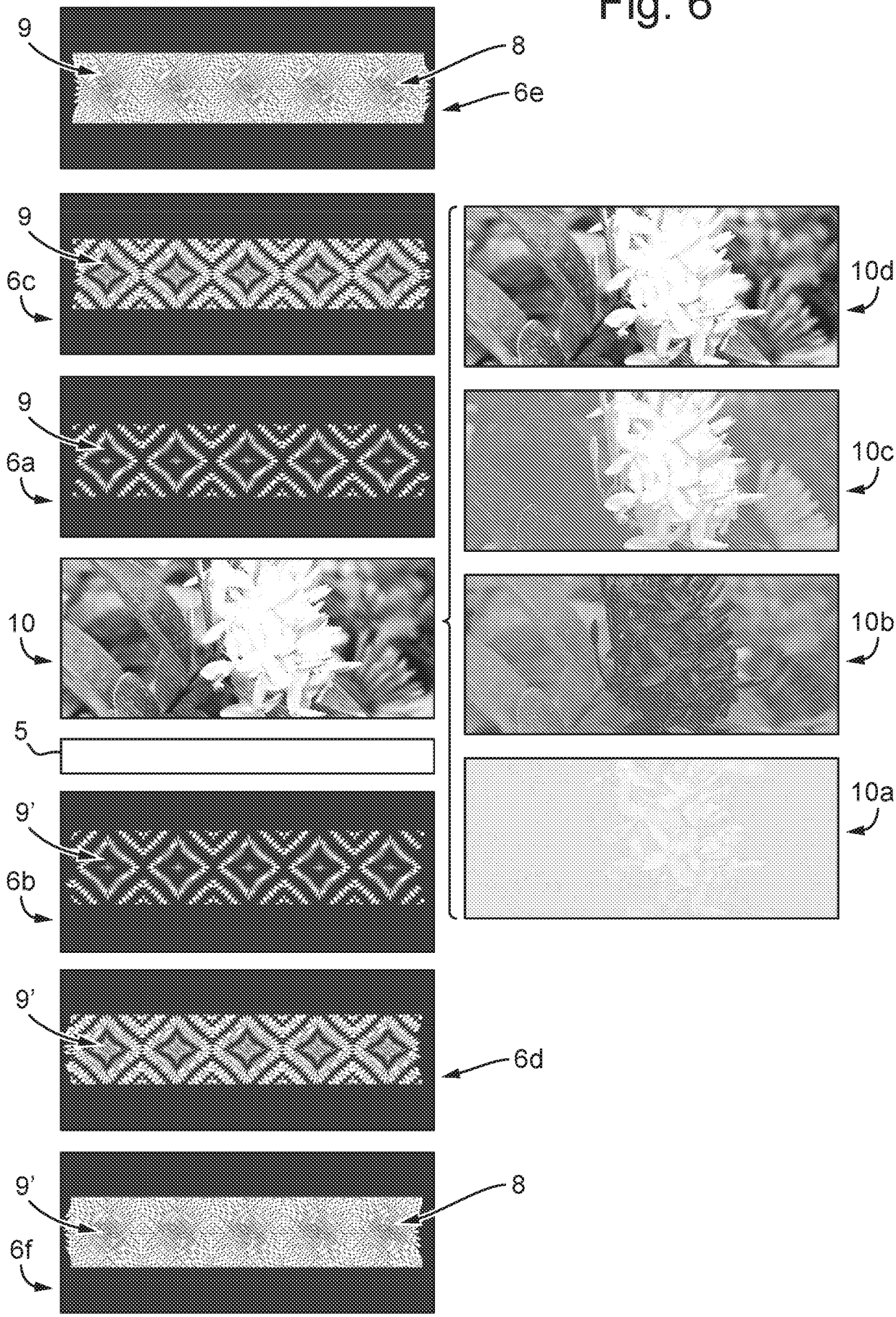


Fig. 7(a)

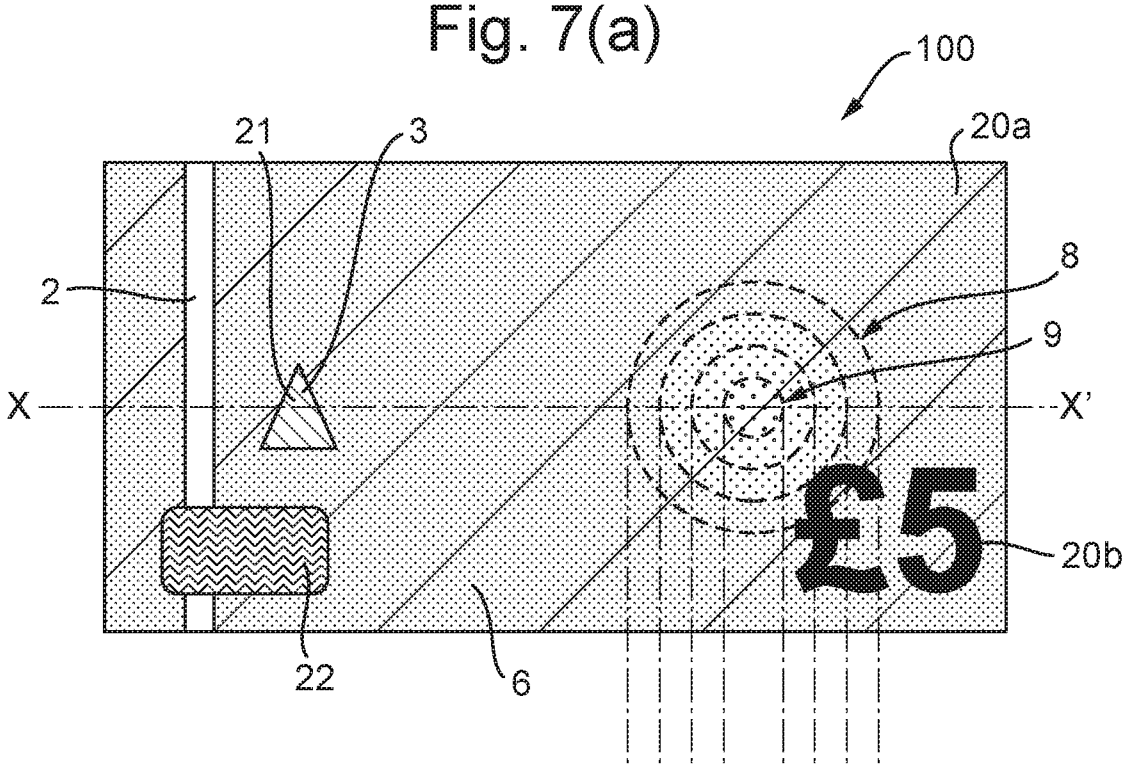
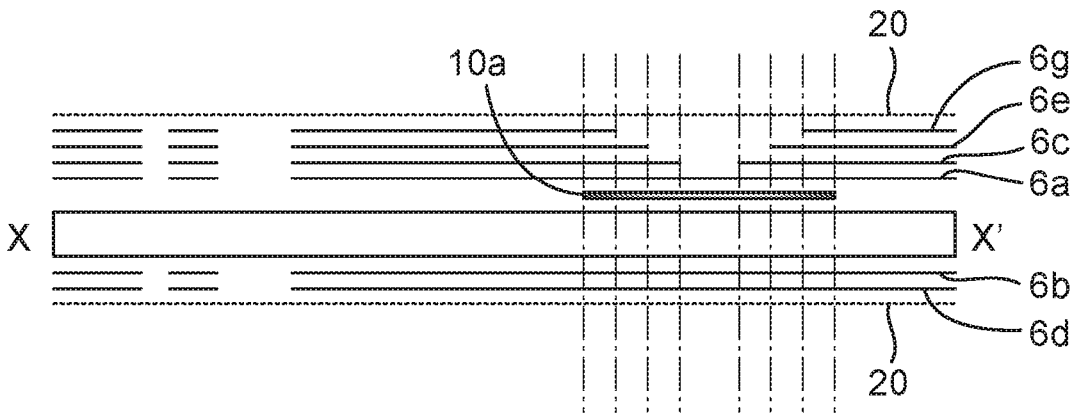


Fig. 7(b)



INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2016/052997

A. CLASSIFICATION OF SUBJECT MATTER
INV. B42D25/23 B42D25/24 B42D25/29 B42D25/351 B42D25/373
B42D25/378 B42D25/45
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

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.
Y	GB 2 076 337 A (GAO GES AUTOMATION ORG) 2 December 1981 (1981-12-02) page 1, line 5 - page 4, line 116; claims 1-11; figures 1-7	1-7, 9-16, 18-22, 24-40, 42-49, 51-55, 57-66

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
9 January 2017	18/01/2017

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Seiler, Reinhold

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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A	EP 2 384 901 A1 (GIESECKE & DEVRIENT GMBH [DE]) 9 November 2011 (2011-11-09) paragraph [0005] - paragraph [0054]; claims 1-14; figures 1-5	1-66
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A	WO 2010/130755 A2 (GIESECKE & DEVRIENT GMBH [DE]; LIEBLER RALF [DE]; KROMBHOLZ MARKUS [DE) 18 November 2010 (2010-11-18) page 16, line 4 - page 22, line 11; claims 1-13; figures 1-4	1-66

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Information on patent family members

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