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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
09 May 2019 (09.05.2019)

WIPO | PCT

(10) International Publication Number
WO 2019/086897 A2

(51) International Patent Classification:
Not classified

(21) International Application Number:
PCT/GB2018/053195

(22) International Filing Date:
02 November 2018 (02.11.2018)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
1718254.4 03 November 2017 (03.11.2017) GB

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

(72) Inventor: **HOLMES, Brian**; Gnomes Oak, Fleet, Hampshire GU51 5HZ (GB).

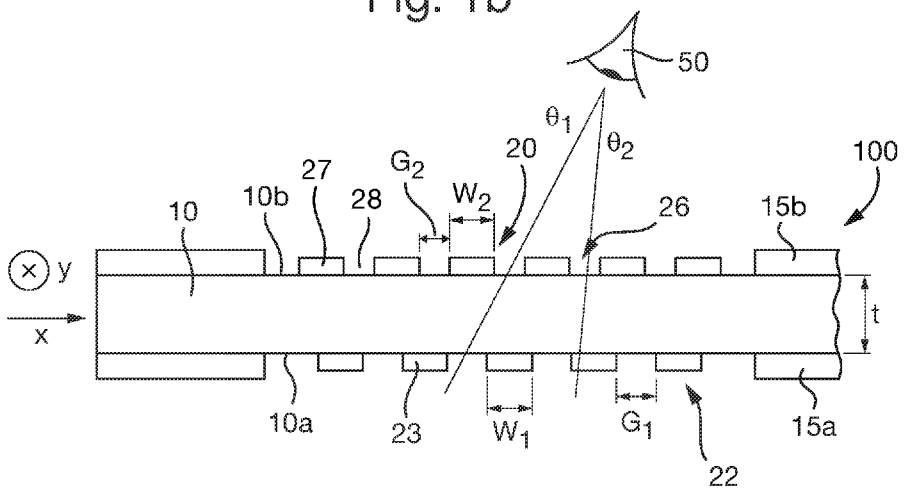
(74) Agent: **GILL JENNINGS & EVERY LLP**; The Broadgate Tower, 20 Primrose Street, London EC2A 2ES (GB).

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

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK,

(54) Title: SECURITY DOCUMENT AND METHOD OF MANUFACTURE THEREOF

Fig. 1b



(57) Abstract: A method of forming a security document is provided. The method comprises: providing a substrate having opposing first and second surfaces, the substrate being substantially transparent to visible light; providing first and second opacifying layers to the first and second surfaces of the substrate respectively, wherein; the first opacifying layer comprises a first pattern of elements having gap regions between the elements, the gap regions configured to a t least partially allow the passage of visible light; the second opacifying layer comprises a second pattern of elements having gap regions between the elements, the gap regions configured to at least partially allow the passage of visible light, and; the first and second patterns of elements at least partially overlap such that the first and second patterns of elements cooperate with each other to exhibit an optically variable effect to a viewer dependent upon viewing angle, and further wherein; the gap regions of both the first and second patterns of elements are not discernible to the naked human eye, and; at least one of the first and second opacifying layers is provided in a single print working.

WO 2019/086897 A2

[Continued on next page]

EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *without international search report and to be republished upon receipt of that report (Rule 48.2(g))*

SECURITY DOCUMENT AND METHOD OF MANUFACTURE THEREOF

FIELD OF THE INVENTION

The present invention relates to security documents and methods of manufacturing such security documents. The invention has particular application for security documents which are documents of value, such as banknotes, passports, driving licences and the like.

BACKGROUND TO THE INVENTION

To prevent counterfeiting and enable authenticity to be checked, security documents such as banknotes are typically provided with one or more security devices that are difficult or impossible to replicate with commonly available means such as photocopiers, scanners or commercial printers. Examples include features based on one or more patterns such as microtext, fine line patterns, latent images, venetian blind devices, lenticular devices, moiré interference devices and moiré magnification devices, each of which generates a secure visual effect. Other known security device include holograms, watermarks, embossings, perforations, the use of colour shifting or luminescent/fluorescent inks, and even non-visible effects such as those provided by magnetic materials.

Such security devices are conventionally applied to the surface of security documents, for example by the use of a suitable adhesive, or incorporated in a full-window or half-window arrangement. Such a window is a transparent region of the security document which either extends fully through the substrate ("full window") or only on one surface of the substrate ("half-window") such that the security device may be viewed. However, incorporating security devices into security documents in such a manner is time consuming, and requires appropriate registration which may be difficult to effect.

Furthermore, security devices having an optically variable effect such that their appearance is different at different angles of view, have been found to be

particularly effective as their authenticity can be readily checked. However, the visual impact of such devices can be relatively low.

There is therefore a requirement for continual improvement in the field of manufacturing secure documents.

SUMMARY OF THE INVENTION

In accordance with a first aspect of the invention there is provided a method of forming a security document, comprising: providing a substrate having opposing first and second surfaces, the substrate being substantially transparent to visible light; providing first and second opacifying layers to the first and second surfaces of the substrate respectively, wherein; the first opacifying layer comprises a first pattern of elements having gap regions between the elements, the gap regions configured to at least partially allow the passage of visible light; the second opacifying layer comprises a second pattern of elements having gap regions between the elements, the gap regions configured to at least partially allow the passage of visible light, and; the first and second patterns of elements at least partially overlap such that the first and second patterns of elements cooperate with each other to exhibit an optically variable effect to a viewer dependent upon viewing angle, and further wherein; the gap regions of both the first and second patterns of elements are not discernible to the naked human eye, and; at least one of the first and second opacifying layers is provided in a single print working.

In the case of a full or half window arrangement as discussed above in the background section, the window needs to be large enough to incorporate the security device, and the observer is therefore easily able to perceive the region of the security device. In the present invention, the inventors have realised that an extra level of security may be incorporated into a security document if the security device is not immediately discernible to the naked eye, and yet an optically variable effect is exhibited to the viewer dependent upon viewing angle. In particular, in the present invention, the security device (formed by the overlapping patterns of elements) is not discernible to the naked human eye when the document is viewed in reflected light.

In the present invention, this is achieved by providing the first and second opacifying layers having at least partially overlapping patterns of elements that cooperate to generate an optically variable effect, and wherein the gap regions of the patterns of elements are not discernible to the naked eye. As a result, the viewer of such a security document experiences a surprising, yet easily authenticatable optically variable effect when he or she tilts the document so as to change viewing angle, particularly when viewing in transmitted light. In preferred embodiments, the elements of at least one of the first and second patterns of elements are not discernible to the naked eye.

The gap regions of both the first and second patterns of elements have a dimension that is not discernible to the naked human eye. In embodiments where the elements of at least one of the first and second patterns of elements are not discernible to the naked eye, said elements have a dimension that is not discernible to the naked human eye.

Furthermore, at least one of the first and second opacifying layers is provided as a single print working. The inventors have advantageously realised that the optically variable security effect described above may be incorporated into a security document through the provision of the opacifying layer itself, rather than the separate steps of forming the window region and incorporating a security device into said window region. This advantageously speeds up and increases the efficiency of the security document manufacture. Furthermore, as the device is no longer required to be incorporated into a window region, appropriate registration of the first and second patterns of elements is made more straightforward.

Typically, each of the first and second opacifying layers defines at least a part of a window region, and wherein the respective pattern of elements is provided within the window region. Thus, each of the first and second opacifying layers typically comprises a region that is disposed substantially continuously across its respective surface of the substrate, and its respective pattern of elements. The region that is disposed substantially continuously is shaped so as to define at

least a part of a window region, with the pattern of elements being provided within the window region. For example, an opacifying layer may be provided having a substantially continuous region that defines a square, rectangular, circular or other shape window region on its respective surface of the substrate, with the pattern of elements being provided within said window region. At least one of the opacifying layers being provided in a single print working advantageously increases the speed and ease of manufacture of security documents as compared to standard techniques of forming a window region and separately incorporating a security device within the window region.

As the gap regions of the patterns of elements are not discernible to the naked human eye, the window regions are not immediately visible to the observer, especially in reflected light. As the gap regions of the first and second patterns of elements are configured to at least partially allow the passage of visible light, the window regions themselves at least partially allow the passage of visible light.

As the patterns of elements are formed from the opacifying layers that also extend across other regions of the security document, the region of the security document where the patterns of elements overlap to exhibit an optically variable effect (which region may be referred to as a security device) is not discernible to the naked human eye when the document is viewed in reflected light. However, when viewed in transmitted light, the optically variable effect is observed. This concealment of the presence of a security device in reflected light advantageously increases the security level of the document.

Preferably, at least one opacifying layer laterally extends continuously from its respective pattern of elements, typically extending at least 10mm, preferably at least 20mm, from the pattern of elements in at least one direction. Preferably, at least one opacifying layer laterally extends continuously in all directions around its respective pattern of elements for at least 10mm, preferably at least 20mm.

Where the opacifying layers are disposed substantially continuously across the surface of the substrate, this is understood to mean that the opacifying layer has

a negligible variation in optical density. In other words the continuous regions of the opacifying layers may be said to have a substantially continuous, homogenous or uniform optical density. Preferably, the regions of the security document where the opacifying layers are disposed substantially continuously are substantially opaque to visible light.

The opacifying layers may be provided so as to at least partially define one or more further window regions laterally spaced from the respective patterns of elements. Such one or more further windows may for example be provided with security devices in the conventional manner.

Typically, the at least one of the first and second opacifying layers that is provided in a single print working is provided so as to cover at least 50% of the respective surface of the substrate, preferably at least 75%, more preferably at least 90% and even more preferably at least 95%. In preferred embodiments, both the first and second opacifying layers are provided in single print workings, with both opacifying layers provided so as to cover at least 50% of the respective surface of the substrate, preferably at least 75%, more preferably at least 90% and even more preferably at least 95%.

Herein, the term “provided so as to cover at least 50% of the respective surface of the substrate” refers to the opacifying layer extending over, covering or obscuring 50% or more of the surface area of its surface of the substrate, including the respective pattern of elements. It is understood that this refers to the cumulative coverage or area over which the opacifying layer is applied.

Typically, each opacifying layer is provided so as to be disposed on or above its respective surface of the substrate.

The opacifying layers each preferably comprise a non-fibrous, polymeric material 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 which will scatter light (as opposed to allowing clear light transmission therethrough). The opacifying layers will be

translucent to a degree. Regions of the security document may be made substantially opaque to visible light by providing a plurality of such opacifying layers. At least one of such plurality of opacifying layers is typically provided in a single print working.

One or more opacifying layers provided to a surface of the substrate forms an opacifying coating on that surface of the substrate.

The first and second opacifying layers obstruct the passage of visible light by a varying amount dependent on their optical density. The elements of each of the first and second patterns of elements have an optical density greater than their corresponding gap regions.

In a typical polymer banknote for example, 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). Preferably, the difference in optical density between the elements of the first and second patterns of elements and their corresponding gap regions is at least 0.15, preferably at least 0.3, and most preferably at least 0.5, and the thickness of the opacifying layers will be selected in these areas to achieve the desired optical density. Typically the opacifying layers will have a thickness in the range of 1μm to 10μm, preferably 1μm to 5μm.

In embodiments, at least one gap region of at least one of the first and second patterns of elements comprises opacifying layer material. In such embodiments, typically each gap region of the at least one of the first and second patterns of elements will comprise opacifying material.

In other words, the gap regions between the elements of the patterns of elements may comprise opacifying layer material, so long as the optical density difference between the elements themselves and the gap regions is great enough such that the viewer perceives enough contrast such that the optically

variable effect is exhibited. Furthermore, it is not a requirement that the pattern elements themselves are substantially opaque, so long as the optical density difference between them and the corresponding gap regions is large enough.

In embodiments, the elements of at least one of the first and second patterns of elements are substantially opaque.

For example, two or more opacifying layers may be provided to a surface of the substrate, each opacifying layer comprising the same pattern of elements overlaid on top of each other (i.e. in register) such that the resulting pattern elements are substantially opaque to visible light. Typically, each opacifying layer will be provided in a single print working.

In embodiments, the gap regions of at least one of the first and second patterns of elements comprise an absence of opacifying material. In such embodiments, typically each gap region of the at least one of the first and second patterns of elements will comprise an absence of opacifying material.

In the case where the elements of a pattern of elements are substantially opaque and the corresponding gap regions comprise an absence of opacifying material, the contrast between the two is particularly high and thus striking to a viewer.

In accordance with a second aspect of the invention there is provided a method of forming a security document, comprising: providing a substrate having opposing first and second surfaces, the substrate being substantially transparent to visible light; providing first and second patterns of elements to the first and second surfaces of the substrate respectively, wherein each of the first and second patterns of elements comprise gap regions between the elements configured to at least partially allow the passage of visible light, and wherein the first and second patterns of elements at least partially overlap and cooperate with each other to exhibit an optically variable effect to a viewer dependent upon viewing angle, and; providing first and second opacifying layers to the first and second surfaces of the substrate respectively such that the first and second

opacifying layers substantially cover the respective patterns of elements, wherein; the regions of the first and second opacifying layers covering the respective patterns of elements are configured to at least partially allow the passage of visible light.

In a similar manner to the first aspect of the invention, the second aspect of the invention provides a security document having a "concealed" security device that exhibits an optically variable effect to a viewer dependent on viewing angle. The region of the opacifying layer covering the respective pattern of elements is configured to at least partially allow the passage of visible light, and will therefore typically have an optical density of less than 0.5 preferably less than 0.3 and more preferably less than 0.15, such that the optically variable effect generated by the cooperation of the first and second patterns of elements is exhibited. The security device is concealed when the document is viewed in reflected light, with the optically variable effect being observed when viewed in transmitted light.

Typically, at least one of the first and second opacifying layers is provided so as to cover at least 50% of the respective surface of the substrate, preferably at least 75%, more preferably at least 90% and even more preferably at least 95%. The opacifying layer(s) may define at least one window region laterally spaced from the first and second patterns of elements. Typically, at least one of the first and second opacifying layers is provided in a single print working.

Typically, each opacifying layer is provided so as to be disposed on or above its respective surface of the substrate.

Furthermore, the opacifying layers may be provided to cover substantially completely the whole security document substrate (including the regions of the patterns of elements) in a single print working, thereby dramatically reducing production time in comparison to conventional windowed security devices.

Regions of the security document may be made substantially opaque to visible light by providing a plurality of such opacifying layers.

The elements of at least one of the first and second patterns of elements of the second aspect may be substantially opaque. However, in general the resultant optical density in the regions of the elements is greater than the resultant optical density of the gap regions. Here the "resultant optical density" is used to mean the combination of the optical density of the pattern of elements and the covering opacifying layer. Typically this difference in resultant optical density is greater than 0.15, preferably greater than 0.3 and more preferably greater than 0.5.

In the same manner as the first aspect of the invention, the opacifying layers each preferably comprise a non-fibrous, polymeric material 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 which will scatter light (as opposed to allowing clear light transmission therethrough).

The first and/or second pattern of elements of the second aspect may be printed, exposed through a mask, metallised, demetallised or laser-marked, preferably onto or into the transparent substrate. In preferred embodiments, the elements of the first and second patterns of elements are substantially opaque, providing high contrast between the elements and the gap regions. Examples of materials used to form the first and second patterns of elements include vapour deposited metallic materials such as Al and Cu, conventional inks, metallic inks and other materials as would be known to the skilled person.

In the case of both the first and second aspects of the invention, 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 on a banknote for example), 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.

Throughout this specification, the term "visible light" refers to light having a wavelength within the visible spectrum, which is approximately 400 to 750nm. It is most preferable that the visible light is white light, i.e. contains substantially all the visible wavelengths in more or less even proportion.

In both the first and second aspects, the first and second patterns of elements are provided so as to at least partially overlap, and may be fully overlapping or partially overlapping. Importantly, there is at least partial overlap such that the first and second patterns of elements cooperate together to exhibit the optically variable effect. Herein, the region of the security document where the first and second patterns of elements at least partially overlap to exhibit the optically variable effect may be described as a security device.

In both the first and second aspects of the invention, in arrangements where the gap regions comprise opacifying material, at least on the side of the substrate closest to the viewer, the optically variable effect will not be exhibited when the security document is viewed in reflected light due to the scattering properties of the opacifying layer. Instead, the viewer will perceive a uniform region of opacifying layer when viewing in reflection, the optically variable effect thus being "concealed".

However, the optically variable effect is revealed to the viewer in transmitted light, as the gap regions are configured to at least partially allow the passage of visible light. This "concealment" of the integrated security device in reflected light, and the exhibition of the variable optical effect in transmitted light, adds a further level of security to the security document.

Furthermore, in arrangements where the gap regions comprise an absence of opacifying material, the integrated security device is "concealed" when viewed in reflected light. This is due to the fact that the gap regions are not discernible to the naked eye, and that the pattern elements are part of an opacifying layer that extends further over the document.

Throughout this description, the term "transmitted light" is used to mean an arrangement where the viewer and the light source are on opposing sides of the security document, and "reflected light" is used to mean an arrangement where the viewer and light source are on the same side of the security document. It is worth noting that in ambient light conditions, the overall effect when viewed in transmitted light will include reflected light effects, and similarly the overall effect when viewed in reflected light will include transmitted light effects. However, these further effects are negligible and can be ignored for the purposes of this specification.

The following description applies to both the first and second aspects of the invention.

The gap regions of both the first and second patterns of elements may have a dimension of less than 150μm, preferably less than 100 μm and more preferably less than 70μm. In other words, the elements of the first and second patterns of elements may be spaced apart by a dimension of less than 150 μm, preferably less than 100μm and most preferably less than 70μm. In the case of the first aspect of the invention, these dimensions ensure that the gap regions of the first and second patterns of elements are not discernible to the naked eye, particularly at typical viewing distances of between 20 to 80cm. In a similar manner, the elements of at least one of the first and second patterns of elements may have a dimension of less than 150μm, preferably less than 100μm and more preferably less than 70μm, such that the elements themselves are not discernible to the naked eye. In the case of an elongate element such as a rectangular element, this minimum dimension may be the element "width".

Typically, the first and second patterns of elements cooperate with each other to exhibit an optically variable effect to a viewer when the security document is tilted relative to a viewer along a first tilt axis. Preferably, the first tilt axis lies substantially in the plane of the security document. This optically variable effect on tilting is a memorable and easily authenticatable effect that improves the security of the document.

The first pattern of elements may comprise a first set of image elements and at least a second set of image elements, and the pitches and relative locations of the first and second patterns of elements may be such that the first and second patterns of elements cooperate to exhibit the first set of image elements at a first viewing angle and the second set of image elements at a second viewing angle.

Due to the first and second patterns of elements being provided on opposing surfaces of a substantially transparent substrate and therefore being separated along a direction normal to the planes of the patterns, tilting the security device allows the viewer to observe parallax effects due to the separation of the patterns. A viewer will observe, at a first viewing angle, the first set of image elements which typically cooperate together to form a first recognisable image and observe, at a second viewing angle, the second set of image elements which similarly typically cooperate together to form a second recognisable image. This so-called “phase interference” effect provided by the invention provides a memorable effect to a user, and enhanced security of the device.

Typically, at least one of the first and second patterns of elements, or both in combination, are arranged so as to define indicia, preferably a letter, digit, geometric shape, symbol, image, graphic or alphanumerical text. It is envisaged that for the majority of applications, only the first pattern of elements (comprising the first and second sets of image elements) will define indicia. For example, the first set of image elements may define a star shape, and the second set of image elements may also define a star shape but of a smaller size. Tilting the device would then exhibit a dynamic effect of the star growing and shrinking in size. In such a situation, the first and second sets of image elements may be interleaved with each other.

At least one of the first and second patterns of elements comprises one or more patterns of rectilinear lines, curves or circles, or one or more patterns of dots.

The first set of image elements may define indicia at a first spatial location and the second set of image elements may define indicia at a second spatial location

such that when the security document is tilted relative to a viewer along a first tilt axis, the viewer perceives animation of said indicia.

In a preferred arrangement, the first pattern of elements comprises a first set and at least a second set of image elements, and the second pattern of elements comprises a pattern of elements acting as a "parallax barrier" or "sampling pattern" such that at different viewing angles only one of the sets of image elements is viewable through the second pattern of elements. Typically the pitch of such a sampling pattern is substantially equal to or less than the gap between the patterns of elements, in this case the substrate thickness. Typical substrate thicknesses for bank notes for example are in the range of 50-100μm, preferably 70-80μm, and thus a preferred pitch in this instance would be in the range of 50-100μm, preferably 70-80μm dependent on the thickness of substrate used. Typical substrate thicknesses for other security documents such as credit or identity cards or datapages for passports may be in the range of 200-700μm, preferably 500-600μm. The pitches of the patterns of elements will be modified accordingly with, in the case of the first aspect of the invention, at least the gap regions having a dimension such that they are not discernible to the naked eye.

Typically, the first and second sets of image elements are interleaved with each other. In general, for N image channels, the first pattern of elements will be comprised of N interleaved strip patterns of width p / N (where p is the repeat distance (or pitch) of the second pattern of elements when acting as a sampling pattern). Thus each interlaced strip of the first pattern of elements matches a gap region of the second pattern of elements and the first and second patterns of elements cooperate to behave as an N-channel lenticular device.

The first and second patterns of elements may be configured such that a first region of the security document exhibits a first optically variable effect when the security document is tilted relative to a viewer about a first tilt axis, and exhibits a second optical effect different from the first optical effect when the security document is tilted relative to a viewer about a second tilt axis not parallel to the first tilt axis, preferably wherein the first and second tilt axes lie substantially in the plane of the security document. This is a particularly striking visual effect.

Such an effect may be produced by providing a pattern of elements (typically acting as a sampling pattern) having a first region where the elements are orientated in a first direction and a second region where the elements are orientated in a second, different direction. The first and second optical effects will be exhibited upon tilting the document about first and second tilt axes corresponding to the first and second regions. In embodiments, the first and second tilt axes are substantially perpendicular, as the elements of the first and second regions are substantially perpendicular.

The effects discussed above may be described as “phase interference effects”. In embodiments, the first and second patterns of elements may cooperate with each other to exhibit a moiré pattern that varies according to viewing angle. The moiré pattern may be exhibited alternatively to, or in addition to, the phase interference effects.

The pitches and/or relative rotations of the first and second patterns of elements and their relative locations may be such that the first pattern of elements cooperates with the second pattern of elements to generate a magnified version of at least a part of the first pattern of elements due to the moiré effect. The moiré magnification factor depends upon the difference between the periodicities or pitches of the first and second patterns of elements. A pitch mismatch between the two patterns of elements along an axis can be conveniently generated by rotating one pattern of elements relative to the other, such that the two patterns have a rotational misalignment.

Moiré magnification can be utilised to provide a striking optical effect exhibiting different perceived depths within an image. This may be provided in embodiments where at least one of the first and second patterns of elements comprises a first area having a first pitch along at least one axis and a second area having a second pitch along said axis, whereby the moiré effect causes different degrees of magnification of the first pattern of elements to occur, such that a viewer of the security document perceives areas of different depth corresponding to the first and second areas. As above, the pitch mismatch

along an axis may be generated by a rotational misalignment of the patterns of elements.

In embodiments, the first pattern of elements comprises an array of image elements that are compressed along at least the axis along which magnification occurs due to the moiré effect. The compression factor of the image elements is determined such that the magnified image elements exhibited to a viewer of the security document have the desired aspect ratio. The image elements may be arranged to define indicia, preferably a letter, digit, geometric shape, symbol, image, graphic or alphanumerical text. In the case of the first aspect of the invention where the patterns of elements are provided by the opacifying layers themselves, this advantageously allows for increased ease of personalisation of the security document, as different patterns of elements may be provided as desired.

At least one image element may comprise at least two sub-elements configured to have different degrees of magnification such that a viewer perceives the image element in the variable image to have a three dimensional appearance.

The pitch of the array of image elements may vary continuously along at least one axis of at least one region, whereby the moiré effect causes different degrees of magnification of the image elements to occur, such that a viewer of the security document perceives that the magnified image elements are located on a first image surface that is tilted or curved with respect to the surface of the security document. This provides a document that exhibits an image plane or surface that is appears noticeably tilted or curved relative to the plane of the document. This visual effect significantly enhances the visual appearance of the security document and, moreover, enhances the security level associated with the document since the necessary pitch requirements of the first and second patterns of elements increases the complexity of manufacture and deters would-be counterfeiters.

The pitch of the array of image elements may vary in a linear (constant gradient) or non-linear (variable gradient) manner.

It should be noted that, due to the potential for the variable images generated by the device to appear curved, the term “image surface” will generally be used in place of “image plane”. However, in places where the latter term is used, it will be appreciated that the term “plane” is not limited to being flat unless otherwise specified.

The term “continuously varies” in this context means that the pitch variation across the array of image elements is such that the resulting image surface on which the magnified image elements are perceived in the variable image appears smooth to the human eye. In general the pitch of at least one pattern of elements may vary continuously along at least one axis of at least one region.

The image elements in the array can all be identical in size, in which case the varying magnification levels across the device will cause size distortion. This can be used as a visual effect in itself. However, in preferred embodiments, the size of the image elements varies in a corresponding manner such that the viewer perceives that the magnified image elements have substantially the same size as each other on the first image surface.

In some embodiments the pitches of the first and second patterns of elements and their relative locations are such that a first image surface is positioned in front of or behind the surface of the security document. In other advantageous implementations, the pitches of the first and second patterns of elements and their relative locations are such that a first image surface intersects the surface of the security document.

In preferred embodiments, both the first and second opacifying layers are provided in respective single print workings. In embodiments of the first aspect of the invention where the opacifying layers provide the first and second patterns of elements, this is particularly advantageous as the speed of production of the security documents is increased compared to, for example, documents having a security element provided in a window arrangement. This also allows for easier registration of the patterns and personalisation of the document.

Typically at least one of the first and second opacifying layers is provided by one of gravure, flexographic or screen printing.

Preferably at least one of the first and second opacifying layers is at least partially electrically conductive such that it can dissipate static charge. In other words, at least one of the first and second opacifying layers is sufficiently electrically conductive so as to avoid the build-up of static charge.

In accordance with a third aspect of the present invention there is provided a security document comprising: a substrate having opposing first and second surfaces, the substrate being substantially transparent to visible light, wherein; the first and second surfaces of the substrate comprise respective first and second patterns of elements, wherein each of the first and second patterns of elements comprise gap regions between the elements configured to at least partially allow the passage of visible light, and wherein the first and second patterns of elements at least partially overlap and cooperate with each other to exhibit an optically variable effect to a viewer dependent upon viewing angle, the security document further comprising; first and second opacifying layers provided on the first and second surfaces of the substrate respectively such that the first and second opacifying layers substantially cover the respective patterns of elements, wherein; the regions of the first and second opacifying layers covering the respective patterns of elements are configured to at least partially allow the passage of visible light.

Typically, at least one of the first and second opacifying layers is provided so as to cover at least 50% of the respective surface of the substrate, preferably at least 75%, more preferably at least 90% and even more preferably at least 95%. The opacifying layer(s) may define at least one window region laterally spaced from the first and second patterns of elements. Typically, at least one of the first and second opacifying layers is provided in a single print working.

Typically, each opacifying layer is provided so as to be disposed on or above its respective surface of the substrate.

Preferred embodiments of the third aspect of the invention are set out in the appended claims and have advantages substantially as discussed above.

In accordance with a fourth aspect of the invention there is provided a security document made in accordance with the first or second aspects.

The security document of any of the aspects of the invention may be any of: currency, an identification document, an identification card, a passport, a licence, a certificate of authenticity, a cheque, a stamp or other document of value.

In any of the aspects, more than one opacifying layer may be provided to a surface of the substrate of the security document. For example, regions of the security document may be made substantially opaque to visible light by providing a plurality of such opacifying layers.

BRIEF DESCRIPTION OF THE DRAWINGS

Figures 1a and 1b illustrate schematic plan and cross-sectional views, respectively, of a security document according to an embodiment of the invention;

Figures 2a and 2b schematically illustrate the optically variable effect exhibited by a security document according to an embodiment of the invention;

Figure 3 is a cross-sectional view of a security document according to a further embodiment of the invention;

Figure 4 is a cross-sectional view of a security document according to a further embodiment of the invention;

Figure 5 illustrates an example sampling pattern of elements that may be used according to an embodiment of the invention;

Figures 6a and 6b illustrate an artwork pattern of elements that may be used according to an embodiment of the invention;

Figures 7a and 7b schematically illustrate the optically variable effect generated by the combination of the patterns of elements in Figures 5 and 6;

Figure 8 illustrates an example sampling pattern of elements that may be used together with an artwork pattern of elements as illustrated in Figures 9a and 9b to exhibit that optically variable effect illustrated at Figure 10;

Figure 11 illustrates an example artwork pattern of elements that may be used to exhibit a moiré magnification effect, illustrated at Figure 12;

Figures 13a and 13b illustrate an example sampling pattern of elements having a variable pitch;

Figures 14a and 14b illustrate an artwork pattern of elements that may be used in combination with the sampling pattern of Figure 13 to exhibit that optically variable effect illustrated at Figure 15;

Figure 16 and 17 schematically illustrate an example artwork pattern that may be used to exhibit a three-dimensional effect, and;

Figures 18a and 18b illustrate example complex patterns of elements that provide a complex optically variable effect as illustrated at Figure 19.

DETAILED DESCRIPTION

Figures 1a and 1b illustrate schematic plan and cross-sectional views, respectively, of a security document 100 according to an embodiment of the invention. The cross-section of Figure 1b is taken along X-X' shown in Figure 1a. In this particular example the security document is a banknote, although the skilled person will appreciate that the security document could alternatively be an identification document, an identification card, a passport, a licence, a certificate of authenticity, a cheque, a stamp or other document of value.

The banknote 100 comprises a substantially transparent substrate 10 having opposing first and second surfaces 10a, 10b. On a first surface 10a of the substrate, a first opacifying layer 15a is provided, and on the opposing second surface 10b, a second opacifying layer 15b is provided, as seen clearly in Figure 1b. The first opacifying layer 15a is provided on the first surface 10a of the substrate so as to define a first pattern of elements (shown generally at 22), and the second opacifying layer 15b is provided on the second surface 10b of the substrate so as to define a second pattern of elements (shown generally at 26).

The first and second patterns of elements at least partially overlap so as to define a security device 20 of the security document.

For ease of description, only one opacifying layer on each surface of the transparent substrate is shown. However, it will be appreciated that more than one opacifying layer may be provided to each surface of the substrate.

As can be seen in Figures 1a and 1b, opacifying layer 15b defines a substantially square window region within which its pattern of elements 26 are provided. Similarly, opacifying layer 15a defines a substantially square window region within which its pattern of elements 22 are provided.

The opacifying layers extend across the remainder of the document substrate and are printed on in a conventional manner to define information, for example a currency denomination (110). Other security devices (such as 120) may be provided as is known in the art. For example, the opacifying layers 15a, 15b may define a circular window region 120 within which a further security device is provided. For simplicity of description, only the region 20 of the opacifying layer comprising the overlapping patterns of elements will be described.

Where the opacifying layers are provided continuously, the bank note is substantially opaque to visible light.

The first pattern of elements 22 comprises a plurality of elements 23 and gap regions 24. In this particular example, the elements of the plurality of elements are substantially opaque, and the gap regions comprise an absence of opacifying layer material. Similarly, the second pattern of elements 26 comprises a plurality of elements 27 separated by gap regions 28. In this particular example, the elements 27 are substantially opaque, and the gap regions 28 comprise an absence of opacifying layer material. However, as described above, it is not a requirement that the pattern elements themselves are substantially opaque, so long as the optical density difference between them and the corresponding gap regions is large enough to exhibit the optically variable effect.

The first and second patterns of elements at least partially overlap such that an optically variable effect exhibited is exhibited to a viewer of the banknote 100 due to the cooperation of the first and second patterns of elements.

The gap regions in both the first and second patterns of elements have a dimension (illustrated at G1 and G2) less than 150μm, preferably less than 100μm and more preferably less than 70μm such that they are not discernible to the naked human eye, particularly at typical viewing distances of between 20-80cm. The gap regions within a pattern of elements may vary in size, but each one will have a dimension such that it is not discernible to the naked eye.

It is furthermore preferable that the dimensions of the elements of the first and second patterns of elements are also not discernible to the naked eye, and thus these have a dimension (illustrated at W1 and W2) of less than 150μm, preferably less than 100μm and more preferably less than 70μm. Again, the elements within a pattern of elements may vary in size.

In this example, both the first and second patterns of elements comprise a linear array of substantially opaque rectangular elements having their long axes orientated in the direction of the Y axis in the view of Figures 1a and 1b. In each of the first and second patterns, the ratio of the element width W to the gap width G is 1:1, with the dimensions of the first and second patterns of elements being substantially the same. The pitch of the first and second patterns of elements (G+W) is substantially equal to or less than the thickness t of the substrate. For a banknote, the thickness t of the substrate (and therefore the pitch of the patterns of elements) is typically in the range of 50-100μm, preferably 70-80μm. In this example, the rectangular elements of both the first and second patterns, as well as the gap regions, have a width of 40μm.

At a first viewing angle Θ1 (see Figure 1b), the two patterns of elements are such that the elements of the first pattern of elements 22 are not visible when viewed through the second pattern of elements 26 (i.e. light is not obstructed by the first pattern of elements). Therefore, when viewing the security device 20 at

first viewing angle Θ1, a viewer 50 perceives only the second pattern of elements, as schematically illustrated at Figure 2a. The security device 20 appears as a series of alternating light and dark areas defined by the second pattern of elements 22.

However, at viewing angle Θ2, the two patterns of elements are such that the elements 23 of the first pattern of elements are visible through the second pattern of elements (i.e. light is obstructed by the first pattern of elements). Therefore, when viewing the security device at second viewing angle Θ2, a viewer 50 perceives both sets of elements, and therefore the security device 20 has a uniform dark appearance, as schematically illustrated in Figure 2b. Here different shading is used to distinguish between the elements of the first and second patterns of elements.

At viewing angles intermediate between Θ1 and Θ2, the first pattern of elements 22 will obstruct light to a varying degree such that the device 20 will exhibit a striped appearance with varying contrast between the elements 27 of the second pattern of elements, and the regions between them.

The change in viewing angles is typically effected by tilting the security document about a tilt axis (O-O' in Figure 1a). Here the tilt axis is substantially parallel with the direction of the elements of the first pattern of elements.

The change in contrast of the security device 20 upon tilting the security document 100 is a memorable and easily authenticatable effect. Furthermore, this effect is simple to achieve through the printing of the opacifying layers onto the transparent substrate 10 of the document 100, removing the requirement to form a windowed area in which to provide a security device, as per the state of the art.

Furthermore, due to the gap regions of the patterns of elements not being discernible to the naked eye and the lack of contrast between the first and second patterns of elements, in reflection the viewer will perceive a uniform region of the opacifying layer in the region of the security device (i.e. the security

device will be "concealed"), with the optically variable effect being strongly exhibited when viewed in transmitted light.

The detailed description so far has referred to the elements of the first and second patterns of elements being substantially opaque, and the gap regions as comprising an absence of opacifying layer material. However, as will now be explained, such an optically variable effect may be generated using patterns of elements so long as there is a difference in optical density between the elements themselves and the gap regions. This is schematically illustrated in Figures 3 and 4 which are described below.

Figure 3 is a cross-sectional view of a security document 100, such as a banknote, along X-X' according to a further embodiment of the invention. In the same manner as described above in relation to Figure 1b, first 15a and second 15b opacifying layers are provided to respective first and second surfaces of the substrate 10. However, here, the gap regions 24, 28 comprise opacifying layer material. The thickness of the opacifying layer in the gap regions 24, 28 is smaller than that of the elements 23, 27 of the patterns of elements such that there is an optical density difference between the elements and associated gaps. As a result, the elements and the gaps obstruct light to a different degree and the variable optical effect is still exhibited to a viewer 50. The difference in thickness of the opacifying layer in the regions of the elements and the gaps is chosen such that the optical density of the elements is greater than the optical density of the gaps by at least 0.15, preferably by at least 0.3 and most preferably by at least 0.5. Similarly, the elements themselves need not be substantially opaque so long as the optical density difference is achieved.

When viewing in reflected light, the optically variable effect will not be visible due to light scattering by the opacifying layer present in the gap regions, and the security device will not be perceived by the viewer. However, the optically variable effect will be revealed when viewing in transmitted light.

As explained above in relation to Figure 3, an opacifying layer may be printed having varying thickness corresponding to the pattern elements and gap regions.

Alternatively, the difference in opacifying material thickness between the pattern elements and the gap regions on a side of the security document 100 may be effected by providing an opacifying layer comprising a pattern of elements over a region of an opacifying layer that is disposed continuously over the substrate (i.e. absent of a pattern of elements), or vice-versa. At least one opacifying layer comprising a pattern of elements is provided in a single print working.

Figure 4 is a cross-sectional view of a security document 100, such as a banknote, along X-X' according to a further embodiment of the invention. Here, the first 22 and second 26 patterns of elements are defined by an at least partially opaque patterning material provided onto the substrate, illustrated at 30. The first and second patterns of elements defined by patterning material 30 are then substantially completely covered by first 15a and second 15b opacifying layers. The opacifying layers 15a and 15b have a thickness in the regions covering the patterning material such that they are at least partially transparent to visible light, such that light is able to be transmitted through the gap regions defined by the patterning material 30. Taking the first pattern of elements 22 as an example, resultant elements are illustrated at 23 as comprising the patterning material 30 and the covering opacifying layer 15a. Resultant gap regions are illustrated at 24 as comprising opacifying layer material with no patterning material. Due to the at least partially opaque nature of the patterning material 30, the resultant elements therefore have a larger resultant optical density than the resultant gap regions, providing the required contrast to exhibit the optically variable effect generated by the overlapping patterns of elements.

Due to the concealment of the patterning material 30 by the opacifying layers, the dimensions of the gap regions defined by the patterning material may, in isolation (i.e. without the opacifying layer covering), be visible to the naked eye. In reflected light, a viewer 50 will perceive the opacifying material in the region of the security device, with the optically variable effect being exhibited when viewed in transmitted light.

Furthermore, similarly to the arrangement illustrated in Figure 3, the patterning material 30 may be provided such that the gap regions in the patterns of

elements comprise patterning material, as long as there is the required optical density difference between the elements and the gap regions when covered by the opacifying layer.

The patterning material 30 may be printed, exposed through a mask, metallised, demetallised or laser-marked, preferably onto or into the transparent substrate.

In each of the arrangement illustrated in Figures 1b, 3 and 4, both patterns of elements are described as being formed in the same manner. However, this is not necessarily the case, and it is envisaged that any combination of the arrangements shown in Figures 1b, 3 and 4 may be used in a single security document. For example, one surface of the security document may comprise a pattern of elements formed as seen in Figure 1b, and the opposing surface of said document may comprise a pattern of elements formed as seen in Figure 3. In each of the arrangements described above, the opacifying layers are preferably applied to the substrate by one of gravure, flexographic or screen printing.

Further examples of optically variable effects that may be exhibited due to the cooperation of the first and second patterns of elements (formed in any of the arrangements outlined above) will now be described. For ease of description, in the following examples, the first pattern of elements 22 will be referred to as the "artwork pattern", and the second pattern of elements 26 will be referred to as the "sampling pattern". It will be appreciated that the particular dimensions used in the following examples are for illustrative purposes only, and may be changed as would be understood by the person skilled in the art.

First Example

Figure 5 illustrates an example sampling pattern 26 that may be used in combination with an artwork pattern 22 as shown in Figures 6a and 6b in order to produce a striking "contrast switch" phase interference effect that is schematically illustrated in Figures 7a and 7b. As seen in Figure 7a, at a first viewing angle Θ_1, a first pattern of indicia is exhibited. More specifically, a dark

"5" symbol 121 is displayed against a light background, a dark region 123 outlines a light "£" symbol 122, and two star shapes 124, 125 are exhibited. At a second viewing angle Θ_2, the same symbols are exhibited but the light and dark regions are reversed.

The sampling pattern 26 comprises an array of substantially opaque rectangular elements that are spaced apart by a distance equal to the width of each rectangular element. In other words, the gap regions 28 of the sampling pattern and the rectangular elements 27 themselves have substantially the same width.

The artwork pattern 22 comprises two arrays 22a, 22b of substantially rectangular elements as illustrated in the magnified view of Figure 6b. The two arrays of the artwork pattern are offset from each other such that at a first viewing angle Θ1 only the first array 22a is visible through the gap regions of the sampling pattern (as seen in Figure 7a) and at different viewing angle Θ2 only the second array 22b is visible through the gap regions of the sampling pattern (as seen in Figure 7b).

The two frames of the variable image are observed when tilting the security document about an axis substantially parallel with the long axes of the elements 27 of the sampling pattern 26. For example, in the view of Figure 1a, if the elements of the sampling pattern are parallel with the Y axis, then the variable image may be exhibited by tilting the document about axis O-O'.

Second Example

In the first example described above, the striking "contrast switch" effect was generated due to the artwork pattern comprising two image channels. In the second example, seven image channels are used in order to provide a more complex phase interference effect that exhibits perceived animation upon a change in viewing angle (i.e. tilting of the security document).

Figure 8 is a schematic plan view of a sampling pattern 26 comprising an array of substantially opaque rectangular elements 27 spaced apart by gap regions 28. In this case, as there are seven image channels. The gap regions have a

width that is one seventh of the sampling pattern pitch – here each rectangular element has a width of 600μm and the elements 27 are spaced apart by gap regions 28 of width 100μm The gap regions of the sampling pattern are not discernible to the naked eye.

The corresponding artwork pattern 22 of the second example is schematically illustrated in Figure 9a, and comprises two spaced apart star-shaped indicia 221a, 221b, with Figure 9b illustrating a magnified view of a star 221a. As can be seen in Figure 9b, the star 221a is comprised of a plurality of sections 222a, 222b…222v, with specific sub-sections ("segments") of the star being viewable through the gap regions 28 of the sampling pattern 26 at different viewing angles. The resultant variable image exhibits the effect schematically shown in Figure 10, where for different viewing angles (Θ_1 – Θ_7) when the security device is tilted about a tilt axis substantially parallel with the elements of the sampling pattern 26, different size stars 221a, 222b are replayed. The size ratio between the elements 27 and gap regions 28 of the sampling pattern 26 controls the number of frames that are replayed upon tilting the security document 100 - in this instance there are seven different frames that are exhibited.

In general, for N image channels, each section of the artwork pattern 22 will comprise N interlaced strip patterns of width p/N (where p is the pitch, or repeat distance, of the sampling pattern).

Take for example the viewing angle Θ_1, where the left star 221a is exhibited at its maximum size, and the right star 221b is exhibited in its minimum size. Referring back to Figure 9b, each section of the star comprises seven segments. For example section 222h comprises segments 223a, 223b, 223c, 223d, 223e, 223f, 223g, each having different lengths. Segment 223a corresponds to the frame seen at viewing angle Θ_1 where the star 221a is exhibited at its maximum size, and segment 223g corresponds to the frame seen at viewing angle Θ_7 where the star 221a is exhibited at its minimum size. In other words, referring to only section 222h for ease of explanation, at viewing angle Θ_1, segment 223a is viewable through the gap regions 28 of the sampling pattern 26; at viewing angle Θ_2, segment 223b (which has a smaller length than 223a) is viewable through

the gap regions 28 of the sampling pattern 26, and so on until at viewing angle Θ_7, segment 223g is viewable through the gap regions 28 of the sampling pattern. The parallax allows the sampling pattern to sequentially reveal each star size, one at a time, when the security device is tilted.

Right star 221b is composed of sections and segments in a corresponding manner such that the final security document, when tilted, displays the seven frames illustrated in Figure 10, with one star increasing in size whilst the other star correspondingly decreases in size in order to provide a striking visual effect.

In this illustrative example, the spacing between the two stars 221a, 221b would preferably comprise opacifying material such that the region of the security document exhibiting the optically variable effect is not immediately apparent.

Third Example

The above examples have been directed to examples of phase interference effects that may be utilised in the present invention. Alternatively or in addition, the at least partially overlapping artwork and sampling patterns can also be used to create moiré magnification effects when viewing the final security document, as will be explained in the following.

The degree of magnification achieved is defined by the expressions derived in "The Moire Magnifier", M. Hutley, R Hunt, R Stevens & P Savander, Pure Appl. Opt. 3 (1994) pp. 133-142. To summarise the pertinent parts of this expression, suppose the pitch of the elements of the artwork pattern (G1+W1) is A and the pitch of the elements of the sampling pattern (G2+W2) is B, then the magnification of the artwork pattern elements, M is given by:

$$M = A / SQRT [(Bcos(Theta) – A)^2 – (Bsin(Theta))^2], \quad \text{(Eq. 1)}$$

where Theta equals the angle of rotation between the elements of the artwork and sampling plates.

For small Theta such that cos(Theta)~1 and sin(Theta)~0 and for the case where B≠A, we have,

$$M=A/(B-A). \quad \text{(Eq. 2)}$$

As we can see from Eq. 2 therefore, if the artwork pattern 22 comprises an array of indicia that are compressed along an axis that is perpendicular to the long axis of the sampling pattern elements 27, then the indicia will appear magnified along that axis when viewed through the sampling pattern.

This effect is illustrated in Figures 11 and 12. Figure 11 illustrates an artwork pattern 22 that comprises a "5" symbol in outline, within which are a plurality of arrays 224a, 224b, 224c, 224d, 224e of "£" symbols. The individual "£" symbols are compressed in a direction along the X axis and are regularly spaced. In this specific example, each "£" symbol has a width (i.e. a dimension along the X axis) of 547μm, and the spacing of the symbols is a constant 70μm. The sampling pattern of the second example may be used, having a regular array of 600μm wide rectangular elements separated by 100μm wide gap regions. The rectangular elements 27 of the sampling pattern and the "£" symbols are aligned along the same (Y) axis (i.e. no rotational offset) and so we may use Eq. 2 to calculate the magnification of the artwork pattern "£" indicia. Accordingly, when viewing through the sampling pattern 26, the magnification of the "£" symbols is 617/(700-617) = 7.4x, giving an exhibited width of 4.1mm in the exhibited optically variable image.

Furthermore, when viewing the security document, the viewer perceives 4.1mm wide "£" symbols appearing to have fast movement along the X axis upon tilting the security document about a tilt axis aligned with the Y axis. The apparent movement of the "£" indicia is due to the fact that changing the viewing angle causes the sampling pattern 26 to sample different parts of the artwork pattern 22. The magnification of the "£" symbols also provides perceived depth of the final image, providing a striking effect to the viewer. Figure 12 illustrates the centre-view combined effect of the artwork 22 and sampling 26 patterns, where

the magnified "£" symbols in the arrays 224a, 224b, 224c, 224d, 224e are easily seen.

Fourth example

In the examples described above, the sampling pattern 26 comprises a plurality of equally-spaced rectangular elements. By varying the spacing of the elements of the sampling pattern, we can achieve further optical effects exhibited to a viewer, such as varying the magnification power, the rate of movement of indicia defined in the artwork pattern 22 upon tilting the security document, and also the apparent depth of the indicia of the artwork pattern. The sampling pattern 26 can be non-constant and exhibit a variation of the width of the elements 27 or gap regions 28 (or both). Taking the previously discussed sampling patterns as an example, the rectangular elements 27 and/or the gap regions 28 may vary in width. Such variation may be linear, sinusoidal or any other mathematical function, and when combined with an artwork plate 22 having indicia of constant width and spacing, will exhibit variable magnification in the final exhibited image.

Figures 13a and 13b illustrate such a non-constant sampling pattern 26. The sampling pattern comprises an array of rectangular elements having their long axes orientated along the Y axis. The elements are spaced apart along the X axis in a linearly variable manner. Each element has a width of 210μm with the gap regions between the elements 27 in this example varying linearly from 58μm at x=0 to 30μm at x=X (see Figure 13b).

Figure 14a illustrates an example artwork pattern 22 comprising an array of 200μm wide "£" indicia 225, each of which have been compressed along the X axis (see Figure 14b), and varying in length along the Y axis. The separation between each "£" symbol along the X axis is constant 70μm. A frame of the variable image exhibited by the combination of the artwork pattern 22 with the sampling pattern 26 is illustrated in Figure 15. Here the left-most "£" symbol 225a exhibits the strongest absolute magnification and appears forward with respect to the plane of the security document, whereas the right-most "£" symbol 225b exhibits the smallest absolute magnification and appears closer to the plane of the security document (although still forward).

This depth effect can be explained by using Eq. 2 above, where the absolute magnification of the left-most "£" symbol 225a in a given frame of the exhibited image is given by M=270/(268-270) = -135x. The absolute magnification of the right-most "£" symbol 265b is given by M=270/(240-270) = -9x. Note that both of these absolute magnification values are negative, hence the inversion of the "£" indicia in the artwork pattern 22 such that they appear correctly orientated in the final exhibited image.

The apparent "depth" of the indicia elements in the exhibited image relative to the surface plane (i.e. the plane of the security document) derives from the familiar lens equation relating magnification of an image located a distance V from the plane of a lens of focal length f, this being,

$$M=V/f-1. \qquad \text{(Eq. 3)}$$

In this instance, the distance between the artwork pattern and the sampling pattern – i.e. the thickness of the substrate 10 (which is a constant) substitutes for the focal length in Eq. 3. Therefore, from Eq. 3, we can see that the apparent depth (V) of the left-most indicia symbol 225a is more forward (i.e. more negative) than that of the right-most indicia symbol 225b.

By varying the spacing of the elements of the artwork and/or sampling patterns, the perceived image plane can configured in the desired manner. For example, in Figure 15, the "£" indicia are perceived to be on an image plane that is tilted with respect to the viewer, but forward of the plane of the security document (i.e. appearing to "float"). However, by manipulating the element spacings accordingly, the image plane may be perceived to be curved, be behind the plane of the security document or even intersect the plane of the security document.

When the security document is tilted about a tilt axis parallel with the long axes of the sampling pattern elements (i.e. the Y axis), the "£" indicia appear to move along the X axis due to the sampling effect of the sampling pattern 26. This

provides a particularly striking effect to a viewer. In general, the rate of perceived motion is proportional to the perceived image depth. Therefore, generally, the greater the absolute magnification of the indicia, the faster the apparent movement of the indicia upon tilting of the security document.

The above examples use an artwork pattern having array(s) of indicia of constant spacing together with a sampling plate comprising regions of different spacing in order to provide the differing depth effects in the exhibited image. However, it will be appreciated that the equivalent effects may be provided using indicia in the artwork pattern having varying spacing and a sampling pattern having constant spacing. Furthermore, in some embodiments both the sampling and artwork plates may comprise elements having varying spacing.

Fifth example

Different apparent depths of indicia exhibited in the image can be utilised in order to display objects which appear three dimensional. Consider an indicia element 226 in the shape of a star (see Figure 16) that may be provided by the artwork pattern. If we split the star 226 into a plurality of separate elements (here three concentric star elements 226a, 226b, 226c), and replay each element such that it appears at a different depth in the exhibited image, then the combined star indicia element 226 will appear three dimensional in the image exhibited by the security document.

Figure 17 illustrates a magnified section of a suitable artwork plate 22 that may be combined with a constant spacing sampling pattern 26 in order to replay star indicia 226 having apparent three dimensional properties. The artwork plate comprises an array of inner star elements 226a, an array of intermediate star elements 226b and an array of outer star elements 226c, with the elements of each array having the same dimension along the X axis and being constantly spaced, but the spacing one of array differing from the spacing of another. In this example, each indicia element has a width of 200μm, with the array of outer star elements having the smallest spacing at 50μm, the array of intermediate star elements having a spacing of 55μm and the array of outer star elements having the largest spacing at 65μm. The sampling pattern 26 used comprises

an array of 210μm wide rectangular elements separated by a constant gap size of 35μm.

The absolute magnification of the outer star elements 226c, intermediate star elements 226b and inner star elements 226a is therefore -50x, -25.5x and -13.25x respectively (using Eq.2). Using Eq.3 we can therefore also see that the outer star elements 226c have the strongest absolute magnification and appear very forward with respect to the plane of the security document, with the inner star elements 226a appearing forward of the plane of the security document, but less so than the outer star elements. This therefore creates a striking three dimensional effect to a viewer of the security document, with parallax upon tilting the document. It will be appreciated that with suitable gap dimensions between the individual elements of the artwork pattern arrays, the optically variable image may replay the star indicia appearing in the depth behind the plane of the security document.

In the examples described so far, the sampling pattern 26 comprises an array of rectangular elements having the same orientation, such that the variable optical effect is exhibited when the device is tilted about one axis (aligned with the long axes of the sampling pattern elements). However, the sampling pattern may comprise regions of elements having different orientations (with corresponding regions of the artwork pattern) such that a variable optical effect is exhibited on tilting the document about different axes, in order to provide further security and difficulty of counterfeiting. Furthermore, the sampling pattern, and indeed the artwork pattern, need not be arranged in the form of rectilinear elements, but instead or in addition comprise curves or circles, or one or more patterns of dots.

Sixth Example

The use of complex designs for the artwork and sampling patterns further increases the level of security associated with the device, and for example may incorporate both phase interference and moiré magnification effects in the same security device. Figure 18a illustrates an example sampling pattern 26 having a complex two dimensional line pattern, in this case in the form of a tiger's head. Figure 18b illustrates an example artwork pattern 22 that cooperates with the

sampling pattern 26 in order to generate a complex moiré effect. Figure 19 illustrates a frame of the variable image exhibited by the security document. The combination of the two patterns generates the effects described above, for example moiré magnification of the pupils (shown at 242) and apparent dynamic movement upon tilting of the device (illustrated at 244). The overall effect exhibited to an observer of the device is one of dynamic texture and volume, providing a striking effect that is difficult to counterfeit.

CLAIMS

1. A method of forming a security document, comprising:

providing a substrate having opposing first and second surfaces, the substrate being substantially transparent to visible light;

providing first and second opacifying layers to the first and second surfaces of the substrate respectively, wherein;

the first opacifying layer comprises a first pattern of elements having gap regions between the elements, the gap regions configured to at least partially allow the passage of visible light;

the second opacifying layer comprises a second pattern of elements having gap regions between the elements, the gap regions configured to at least partially allow the passage of visible light, and;

the first and second patterns of elements at least partially overlap such that the first and second patterns of elements cooperate with each other to exhibit an optically variable effect to a viewer dependent upon viewing angle, and further wherein;

the gap regions of both the first and second patterns of elements are not discernible to the naked human eye, and;

at least one of the first and second opacifying layers is provided in a single print working.

2. The method of claim 1, wherein each of the first and second opacifying layers defines at least a part of a window region, and wherein the respective pattern of elements is provided within the window region.

3. The method of claim 1 or claim 2, wherein the at least one of the first and second opacifying layers that is provided in a single print working is provided so as to cover at least 50% of the respective surface of the substrate, preferably at least 75%, more preferably at least 90% and even more preferably at least 95%.

4. The method of any of the preceding claims, wherein the elements of at least one of the first and second patterns of elements are not discernible to the naked human eye.

5. The method of any of the preceding claims, wherein the first and second opacifying layers obstruct the passage of visible light by a varying amount dependent on their optical density, and wherein the elements of each of the first and second patterns of elements has an optical density greater than their corresponding gap regions.

6. The method of claim 5, wherein the difference in optical density between the elements of the first and second patterns of elements and their corresponding gap regions is at least 0.15, preferably at least 0.3, and most preferably at least 0.5.

7. The method of claim 5 or claim 6, wherein the elements of the first and second patterns of elements have an optical density in the range of 0.1 to 0.5, more preferably 0.1 to 0.4, and most preferably 0.1 to 0.3.

8. The method of any of the preceding claims, wherein the elements of at least one of the first and second patterns of elements are substantially opaque.

9. The method of any of the preceding claims, wherein the gap regions of at least one of the first and second patterns of elements comprise an absence of opacifying material.

10. The method of any of claims 1 to 8, wherein at least one gap region of at least one of the first and second patterns of elements comprises opacifying material.

11. A method of forming a security document, comprising:

providing a substrate having opposing first and second surfaces, the substrate being substantially transparent to visible light;

providing first and second patterns of elements to the first and second surfaces of the substrate respectively, wherein each of the first and second patterns of elements comprise gap regions between the elements configured to at least partially allow the passage of visible light, and wherein the first and second patterns of elements at least partially overlap and cooperate with each

other to exhibit an optically variable effect to a viewer dependent upon viewing angle, and;

providing first and second opacifying layers to the first and second surfaces of the substrate respectively such that the first and second opacifying layers substantially cover the respective patterns of elements, wherein;

the regions of the first and second opacifying layers covering the respective patterns of elements are configured to at least partially allow the passage of visible light.

12. The method of claim 11, wherein the resultant optical density in the regions of the elements is greater than the resultant optical density of the gap regions.

13. The method of claim 12, wherein the difference in optical density is greater than 0.15, preferably greater than 0.3 and more preferably greater than 0.5.

14. The method of any of claims 11 to 13, wherein the first and/or second pattern of elements is printed, exposed through a mask, metallised, demetallised or laser-marked, preferably onto or into the transparent substrate.

15. The method of any of claims 11 to 14, wherein the elements of at least one of the first and second patterns of elements are substantially opaque.

16. The method of any of the preceding claims, wherein the gap regions of at least one of the first and second patterns of elements have a dimension of less than 150μm, preferably less than 100μm and more preferably less than 70μm.

17. The method of any of the preceding claims, wherein the elements of at least one of the first and second patterns of elements have a dimension of less than 150μm, preferably less than 100μm and more preferably less than 70μm.

18. The method of any of the preceding claims, wherein the first and second patterns of elements cooperate with each other to exhibit an optically variable

effect to a viewer when the security document is tilted relative to a viewer along a first tilt axis, preferably wherein the first tilt axis lies substantially in the plane of the security document.

19. The method of any of the preceding claims, wherein the first pattern of elements comprises a first set of image elements and at least a second set of image elements, and the pitches and relative locations of the first and second patterns of elements are such that the first and second patterns of elements cooperate to exhibit the first set of image elements at a first viewing angle and the second set of image elements at a second viewing angle.

20. The method of any of the preceding claims, wherein at least one of the first and second patterns of elements, or both in combination, are arranged so as to define indicia, preferably a letter, digit, geometric shape, symbol, image, graphic or alphanumeric text.

21. The method of any of the preceding claims, wherein at least one of the first and second patterns of elements comprises one or more patterns of rectilinear lines, curves or circles, or one or more patterns of dots.

22. The method of any of claims 19 to 21, wherein the first set of image elements defines indicia at a first spatial location and the second set of image elements defines indicia at a second spatial location such that when the security document is tilted relative to a viewer along a first tilt axis, the viewer perceives animation of said indicia.

23. The method of any of claims 19 to 22, wherein the first and second sets of image elements are interleaved with each other.

24. The method of any of the preceding claims, wherein the first and second patterns of elements are configured such that a first region of the security document exhibits a first optically variable effect when the security document is tilted relative to a viewer about a first tilt axis, and exhibits a second optically variable effect different from the first optically variable effect when the security

document is tilted relative to a viewer about a second tilt axis not parallel to the first tilt axis, preferably wherein the first and second tilt axes lie substantially in the plane of the security document.

25. The method of claim 24, wherein the first and second tilt axes are substantially perpendicular.

26. The method of any of the preceding claims, wherein the first and second patterns of elements cooperate with each other to exhibit a moiré pattern that varies according to viewing angle.

27. The method of any of the preceding claims, wherein the pitches and/or relative rotations of the first and second patterns of elements and their relative locations are such that the first pattern of elements cooperates with the second pattern of elements to generate a magnified version of at least a part of the first pattern of elements due to the moiré effect.

28. The method of claim 27, further wherein at least one of the first and second patterns of elements comprises a first area having a first pitch along at least one axis and a second area having a second pitch along said axis, whereby the moiré effect causes different degrees of magnification of the first pattern of elements to occur, such that a viewer of the security document perceives areas of different depth corresponding to the first and second areas.

29. The method of any of claims 26 to 28, wherein the first pattern of elements comprises an array of image elements that are compressed along at least the axis along which magnification occurs due to the moiré effect.

30. The method of claim 29, wherein at least one image element comprises at least two sub-elements configured to have different degrees of magnification such that a viewer perceives the image element to have a three dimensional appearance.

31. The method of claim 29 or claim 30, wherein the pitch of the array of image elements varies continuously along at least one axis of at least one region, whereby the moiré effect causes different degrees of magnification of the image elements to occur, such that a viewer of the security document perceives that the magnified image elements are located on a first image surface that is tilted or curved with respect to the surface of the security document.

32. The method of claim 31, wherein the size of the image elements varies in a corresponding manner such that the viewer perceives that the magnified image elements have substantially the same size as each other on the first image surface.

33. The method of any of claims 26 to 32, wherein the pitch of at least one pattern of elements varies continuously along at least one axis of at least one region.

34. The method of any of claims 26 to 33, wherein the pitches of the first and second patterns of elements and their relative locations are such that a first image surface is positioned in front of or behind the surface of the security document.

35. The method of any of claims 26 to 33, wherein the pitches of the first and second patterns of elements and their relative locations are such that a first image surface intersects the surface of the security document.

36. The method of any of the preceding claims, wherein both the first and second opacifying layers are provided in respective single print workings.

37. The method of any of the preceding claims, wherein at least one of the first and second opacifying layers is provided by one of gravure, flexographic or screen printing.

38. The method of any of the preceding claims, wherein at least one of the first and second opacifying layers is at least partially electrically conductive such that it can dissipate static charge.

39. The method of any of the preceding claims, wherein the security document is any of: currency, an identification document, an identification card, a passport, a licence, a certificate of authenticity, a cheque, a stamp or other document of value.

40. A security document comprising:

a substrate having opposing first and second surfaces, the substrate being substantially transparent to visible light, wherein;

the first and second surfaces of the substrate comprise respective first and second patterns of elements, wherein each of the first and second patterns of elements comprise gap regions between the elements configured to at least partially allow the passage of visible light, and wherein the first and second patterns of elements at least partially overlap and cooperate with each other to exhibit an optically variable effect to a viewer dependent upon viewing angle, the security document further comprising;

first and second opacifying layers provided on the first and second surfaces of the substrate respectively such that the first and second opacifying layers substantially cover the respective patterns of elements, wherein;

the regions of the first and second opacifying layers covering the respective patterns of elements are configured to at least partially allow the passage of visible light.

41. The security document of claim 40, wherein the resultant optical density in the regions of the elements is greater than the resultant optical density of the gap regions.

42. The security document of claim 40 or claim 41, wherein the difference in optical density is greater than 0.15, preferably greater than 0.3 and more preferably greater than 0.5.

43. The security document of any of claims 40 to 42, wherein the first and/or second pattern of elements is printed, exposed through a mask, metallised, demetallised or laser-marked, preferably onto or into the transparent substrate.

44. The security document of any of claims 40 to 43, wherein the elements of at least one of the first and second patterns of elements are substantially opaque.

45. The security document of any of claims 40 to 44, wherein the gap regions of at least one of the first and second patterns of elements have a dimension of less than 150μm, preferably less than 100μm and more preferably less than 70μm.

46. The security document of any of claims 40 to 45, wherein the elements of at least one of the first and second patterns of elements have a dimension of less than 150μm, preferably less than 100μm and more preferably less than 70μm.

47. The security document of any of claims 40 to 46, wherein the first and second patterns of elements cooperate with each other to exhibit an optically variable effect to a viewer when the security document is tilted relative to a viewer along a first tilt axis, preferably wherein the first tilt axis lies substantially in the plane of the security document.

48. The security document of any of claims 40 to 47, wherein the first pattern of elements comprises a first set of image elements and at least a second set of image elements, and the pitches and relative locations of the first and second patterns of elements are such that the first and second patterns of elements cooperate to exhibit the first set of image elements at a first viewing angle and the second set of image elements at a second viewing angle.

49. The security document of any of claims 40 to 48, wherein at least one of the first and second patterns of elements, or both in combination, are arranged

so as to define indicia, preferably a letter, digit, geometric shape, symbol, image, graphic or alphanumeric text.

50. The security document of any of claims 40 to 49, wherein at least one of the first and second patterns of elements comprises one or more patterns of rectilinear lines, curves or circles, or one or more patterns of dots.

51. The security document of any of claims 40 to 50, wherein the first set of image elements defines indicia at a first spatial location and the second set of image elements defines indicia at a second spatial location such that when the security document is tilted relative to a viewer along a first tilt axis, the viewer perceives animation of said indicia.

52. The security document of any of claims 48 to 51, wherein the first and second sets of image elements are interleaved with each other.

53. The security document of any of claims 40 to 52, wherein the first and second patterns of elements are configured such that a first region of the security document exhibits a first optically variable effect when the security document is tilted relative to a viewer about a first tilt axis, and exhibits a second optically variable effect different from the first optically variable effect when the security document is tilted relative to a viewer about a second tilt axis not parallel to the first tilt axis, preferably wherein the first and second tilt axes lie substantially in the plane of the security document.

54. The security document of claim 53, wherein the first and second tilt axes are substantially perpendicular.

55. The security document of any of claims 40 to 54, wherein the first and second patterns of elements cooperate with each other to exhibit a moiré pattern that varies according to viewing angle.

56. The security document of any of claims 40 to 55, wherein the pitches and/or relative rotations of the first and second patterns of elements and their

relative locations are such that the first pattern of elements cooperates with the second pattern of elements to generate a magnified version of at least a part of the first pattern of elements due to the moiré effect.

57. The security document of claim 56, further wherein at least one of the first and second patterns of elements comprises a first area having a first pitch along at least one axis and a second area having a second pitch along said axis, whereby the moiré effect causes different degrees of magnification of the first pattern of elements to occur, such that a viewer of the security document perceives areas of different depth corresponding to the first and second areas.

58. The security document of any of claims 55 to 57, wherein the first pattern of elements comprises an array of image elements that are compressed along at least the axis along which magnification occurs due to the moiré effect.

59. The security document of claim 58, wherein at least one image element comprises at least two sub-elements configured to have different degrees of magnification such that a viewer perceives the image element to have a three dimensional appearance.

60. The security document of claim 58 or claim 59, wherein the pitch of the array of image elements varies continuously along at least one axis of at least one region, whereby the moiré effect causes different degrees of magnification of the image elements to occur, such that a viewer of the security document perceives that the magnified image elements are located on a first image surface that is tilted or curved with respect to the surface of the security document.

61. The security document of claim 60, wherein the size of the image elements varies in a corresponding manner such that the viewer perceives that the magnified image elements have substantially the same size as each other on the first image surface.

62. The security document of any of claims 55 to 61, wherein the pitch of at least one pattern of elements varies continuously along at least one axis of at least one region.

63. The security document of any of claims 55 to 62, wherein the pitches of the first and second patterns of elements and their relative locations are such that a first image surface is positioned in front of or behind the surface of the security document.

64. The security document of any of claims 55 to 62, wherein the pitches of the first and second patterns of elements and their relative locations are such that a first image surface intersects the surface of the security document.

65. The security document of any of claims 40 to 64, wherein both the first and second opacifying layers are provided in respective single print workings.

66. The security document of any of claims 40 to 65, wherein at least one of the first and second opacifying layers is provided by one of gravure, flexographic or screen printing.

67. The security document of any of claims 40 to 66, wherein at least one of the first and second opacifying layers is at least partially electrically conductive such that it can dissipate static charge.

68. The security document of any of claims 40 to 67, wherein the security document is any of: currency, an identification document, an identification card, a passport, a licence, a certificate of authenticity, a cheque, a stamp or other document of value.

69. A security document made in accordance with any of claims 1 to 39.

Fig. 1a

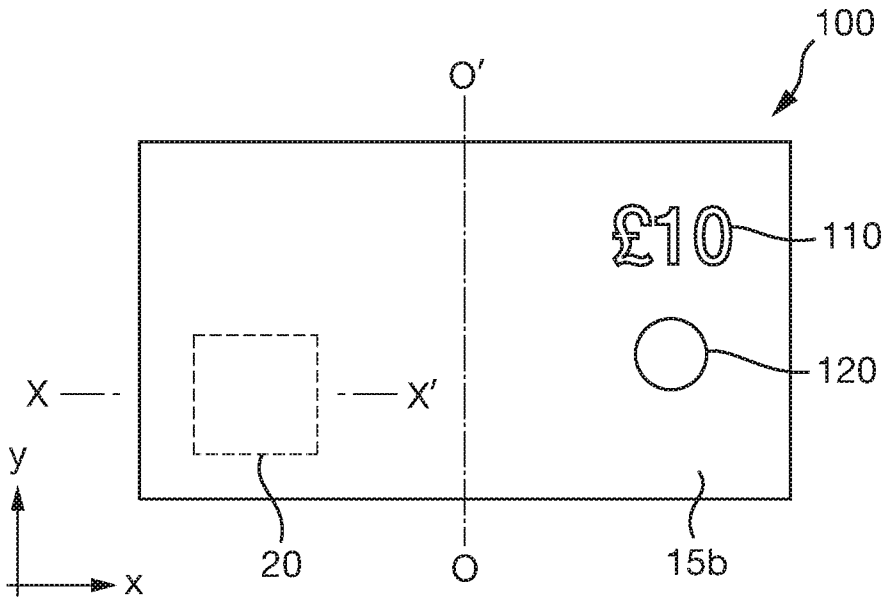

100
O'
£10
110
120
X
X'
y
x
20
O
15b

Fig. 1b

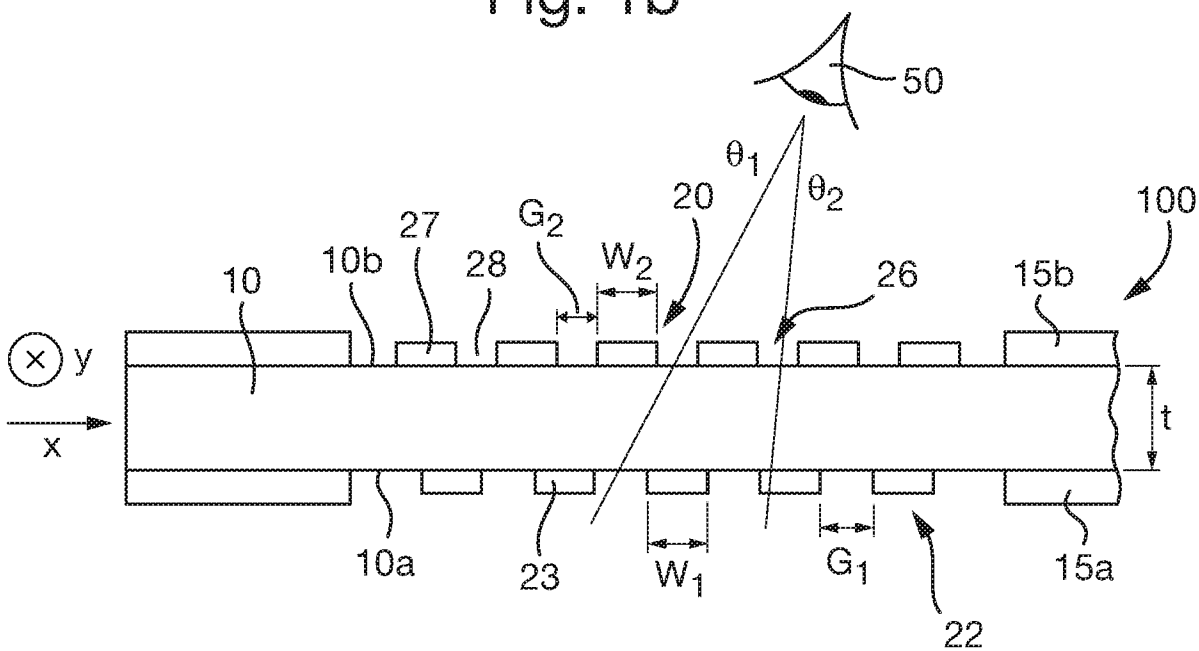

50
θ1
θ2
20
27
G2
W2
100
10
10b
28
26
15b
y
x
t
10a
23
W1
G1
15a
22

Fig. 2a

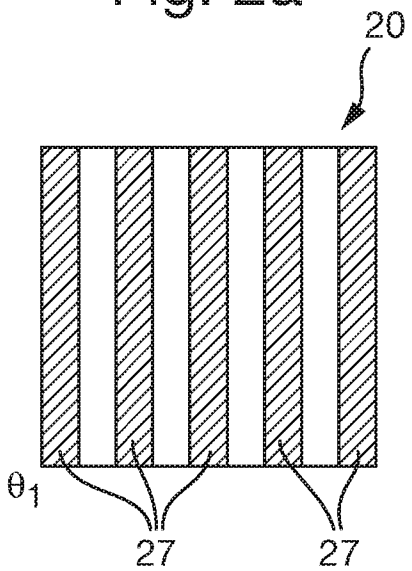


Fig. 2b

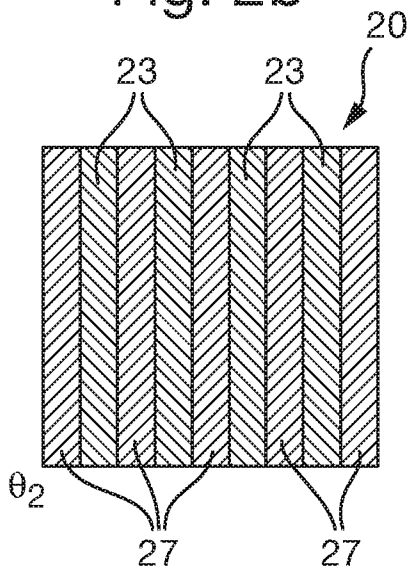


Fig. 3

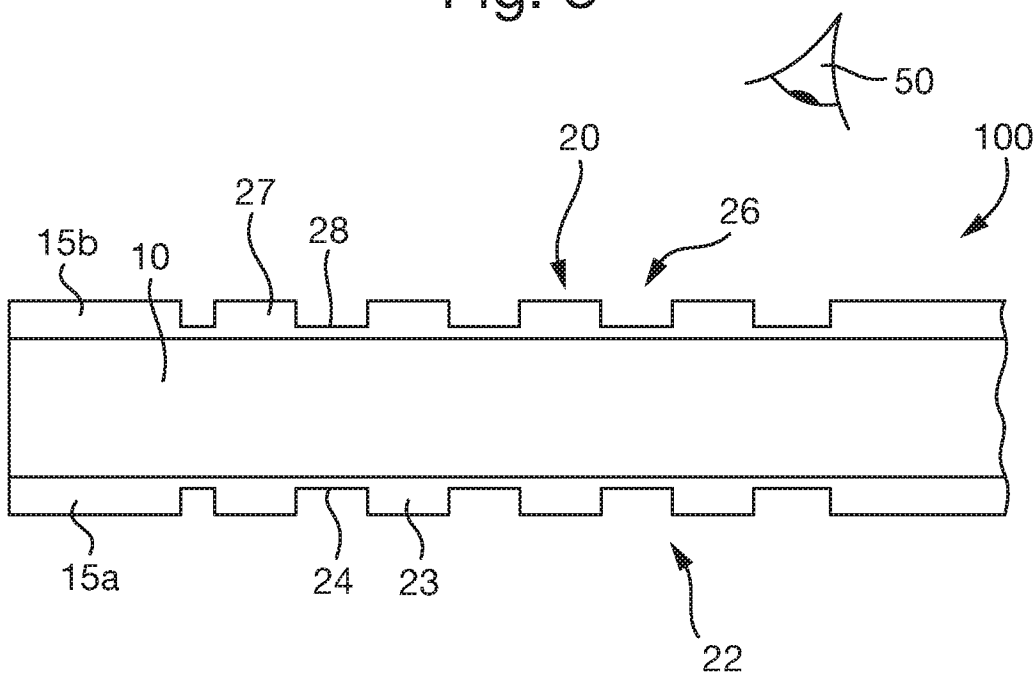


Fig. 4

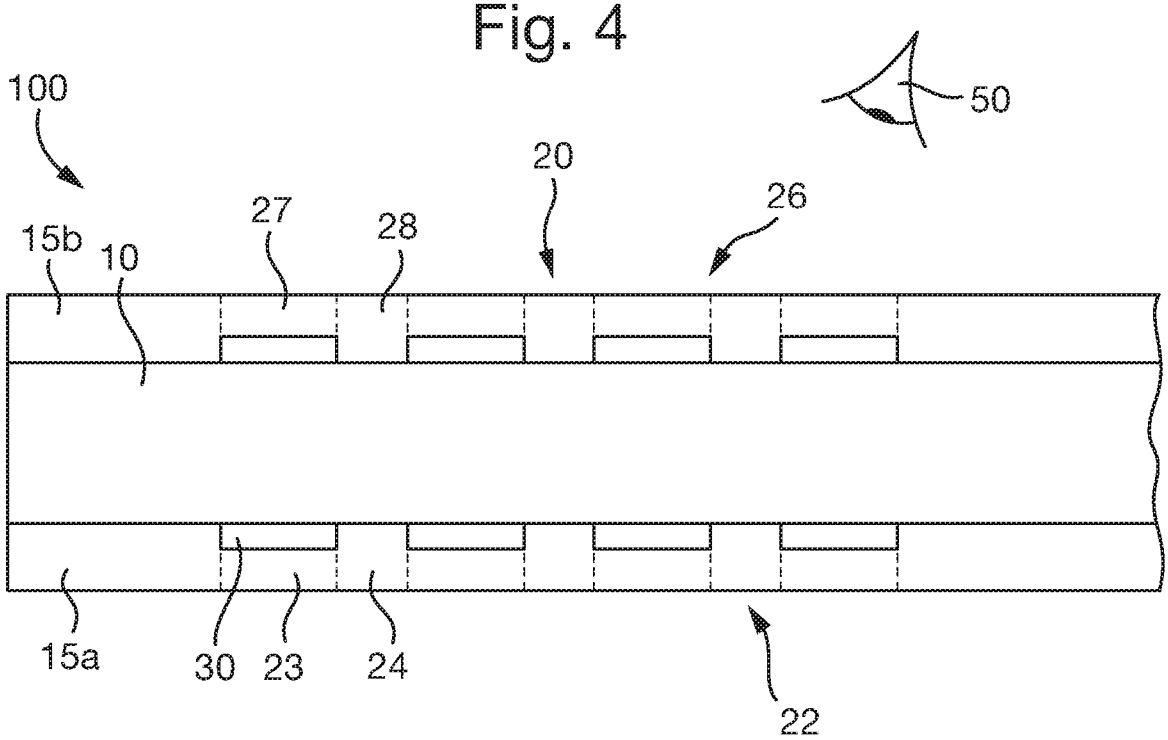


Fig. 5

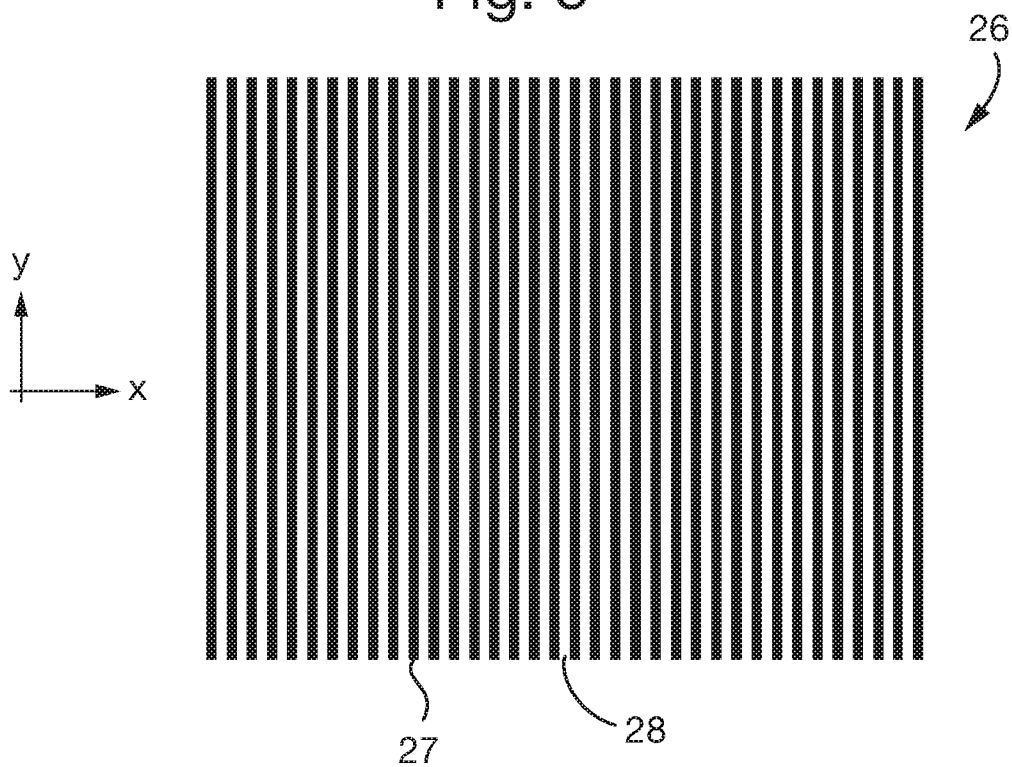


Fig. 6a

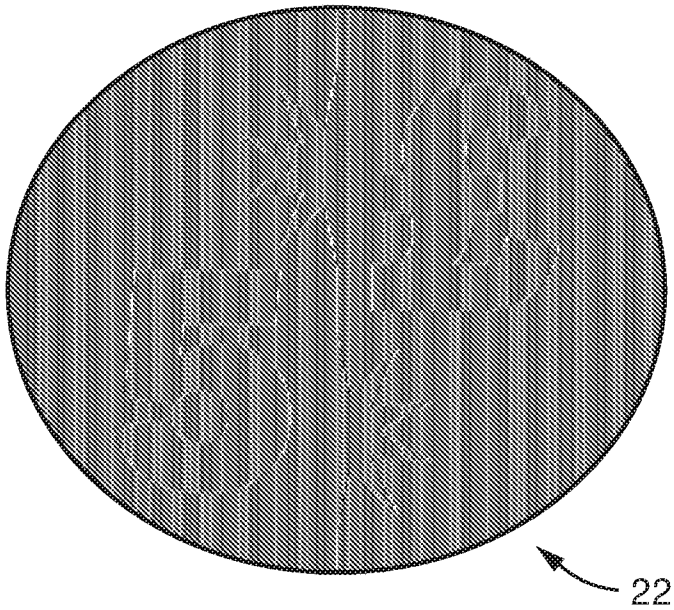


Fig. 6b

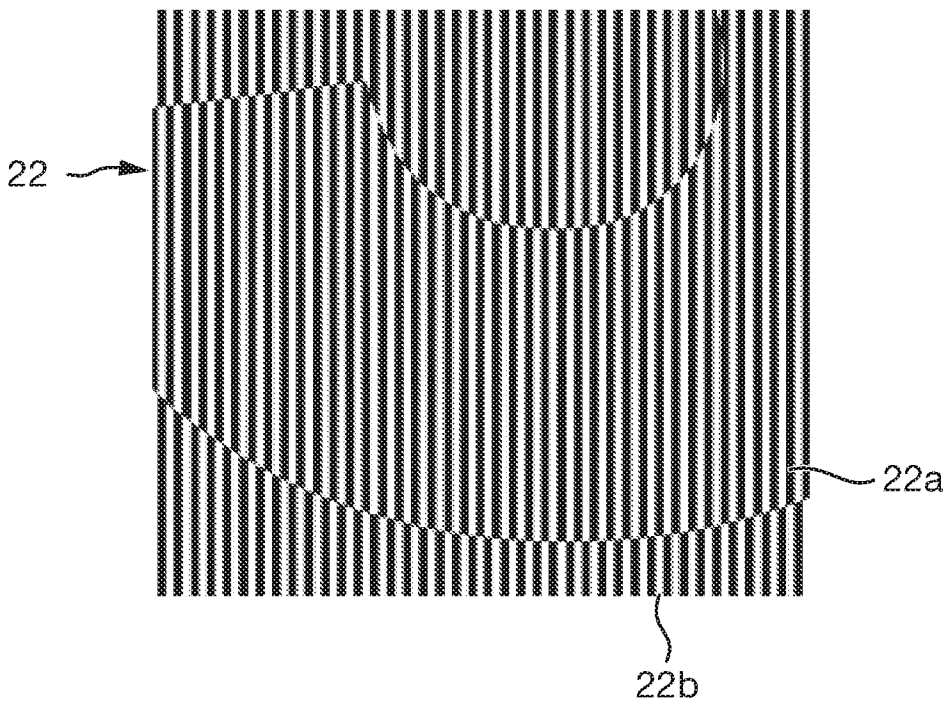


Fig. 7a

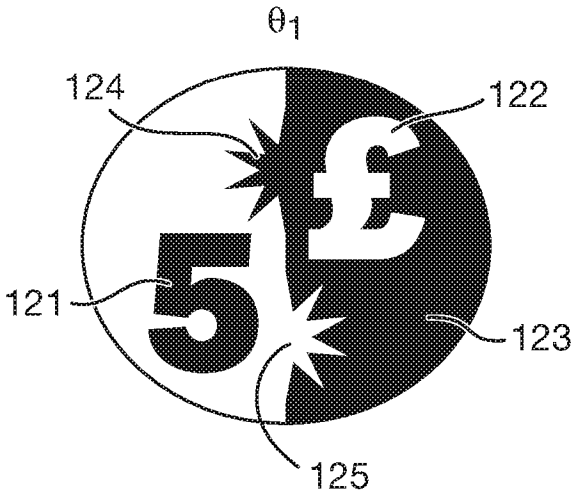


Fig. 7b

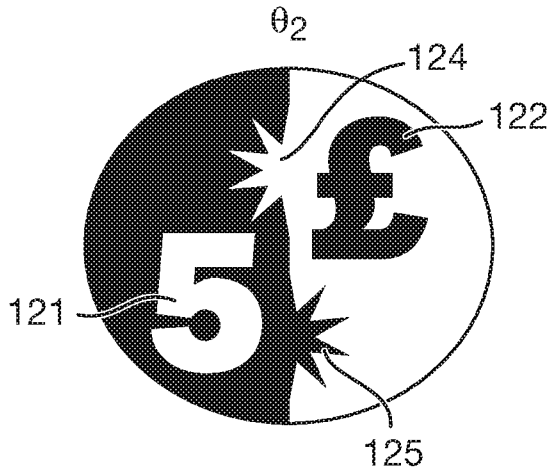


Fig. 8

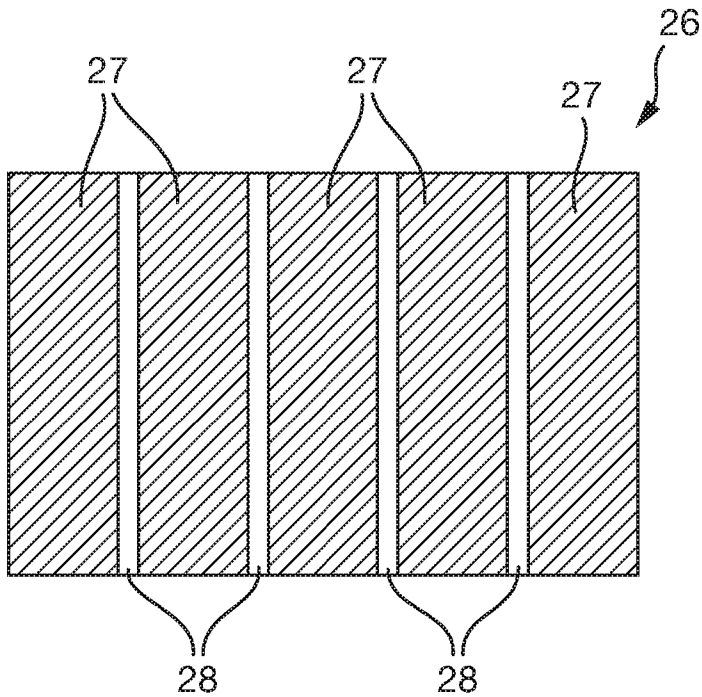


Fig. 9a


221a
221b

Fig. 9b

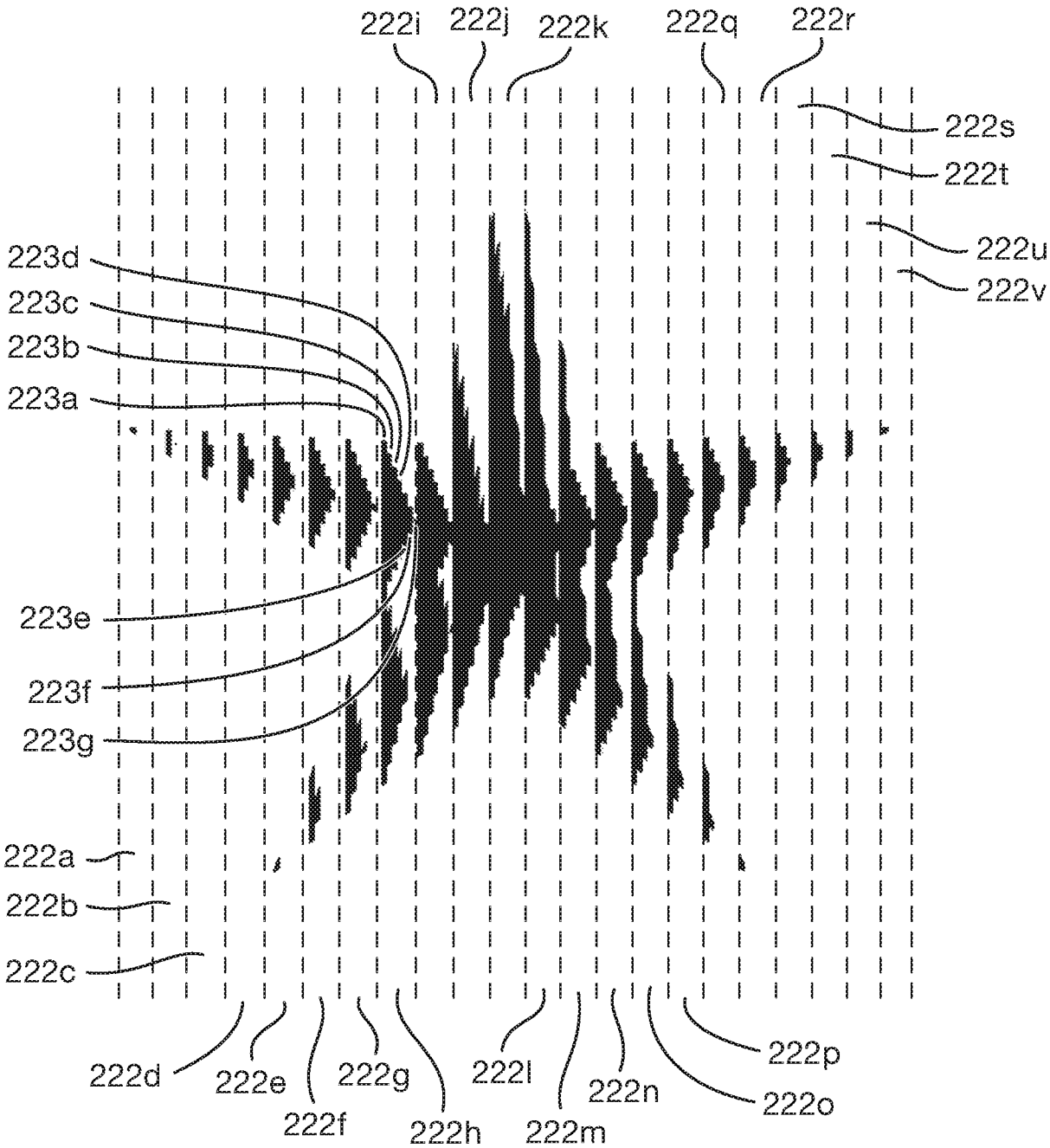

222i
222j
222k
222q
222r
222s
222t
222u
222v
223d
223c
223b
223a
223e
223f
223g
222a
222b
222c
222d
222e
222f
222g
222h
222l
222m
222n
222o
222p

Fig. 10

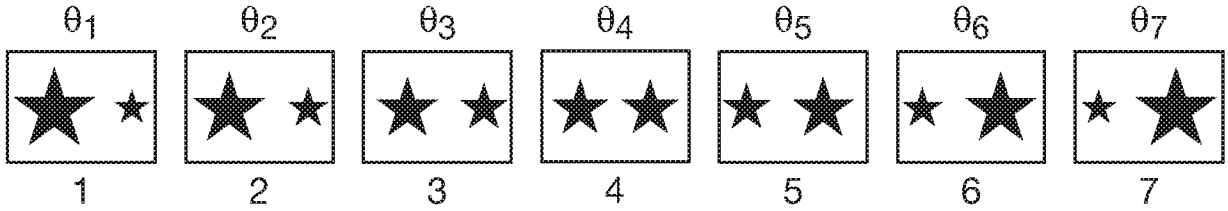


Fig. 11

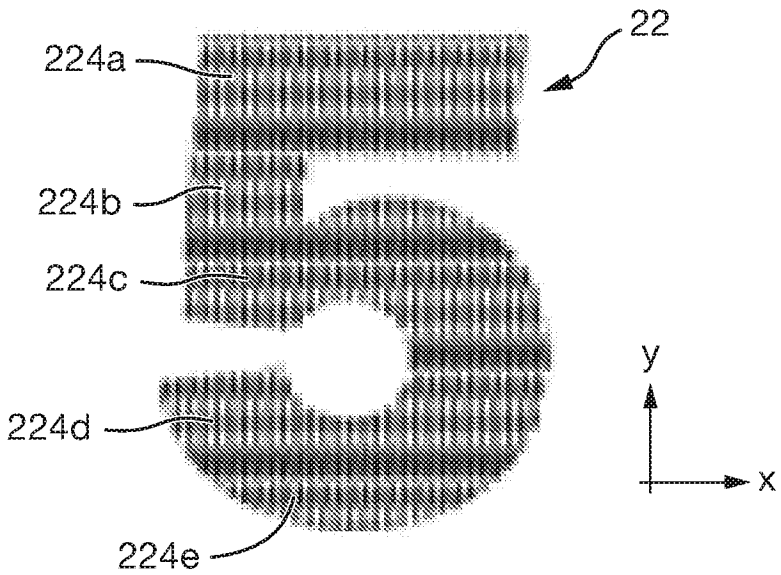


Fig. 12

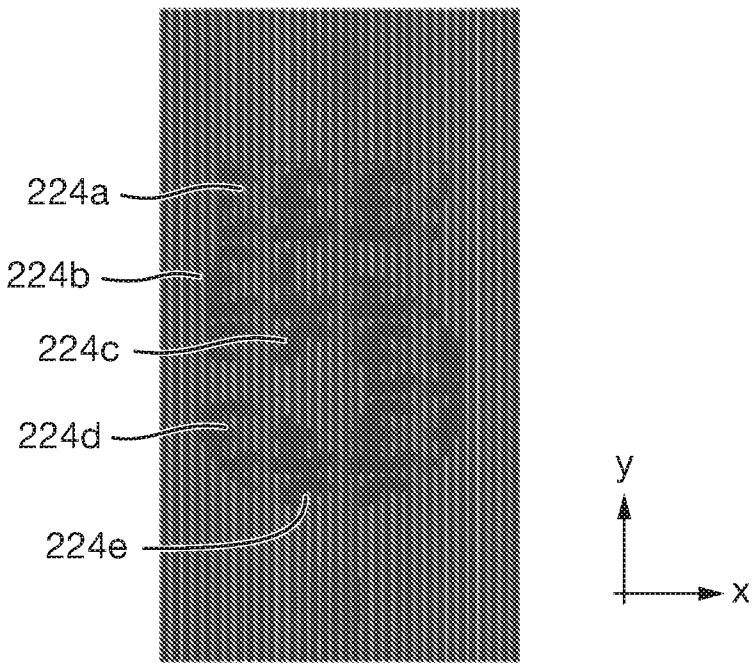


Fig. 13a

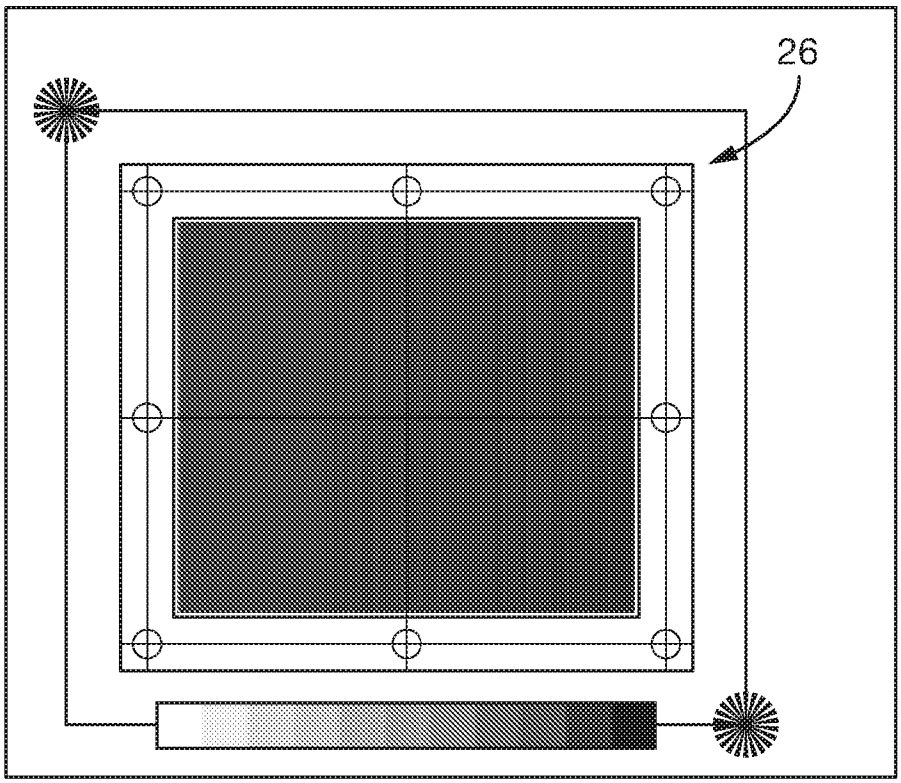


Fig. 13b

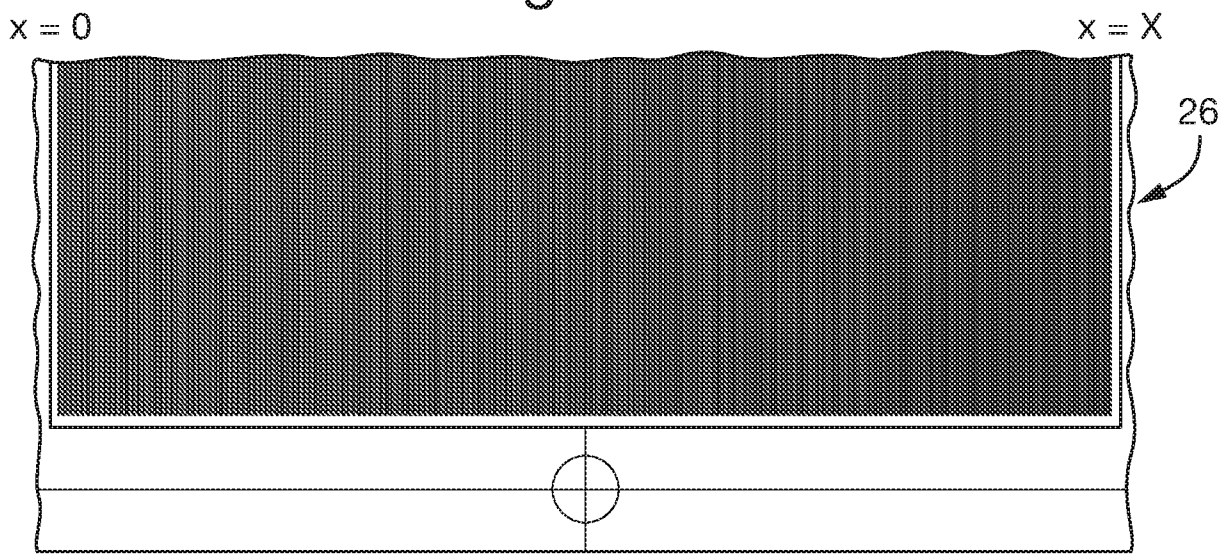


Fig. 14a

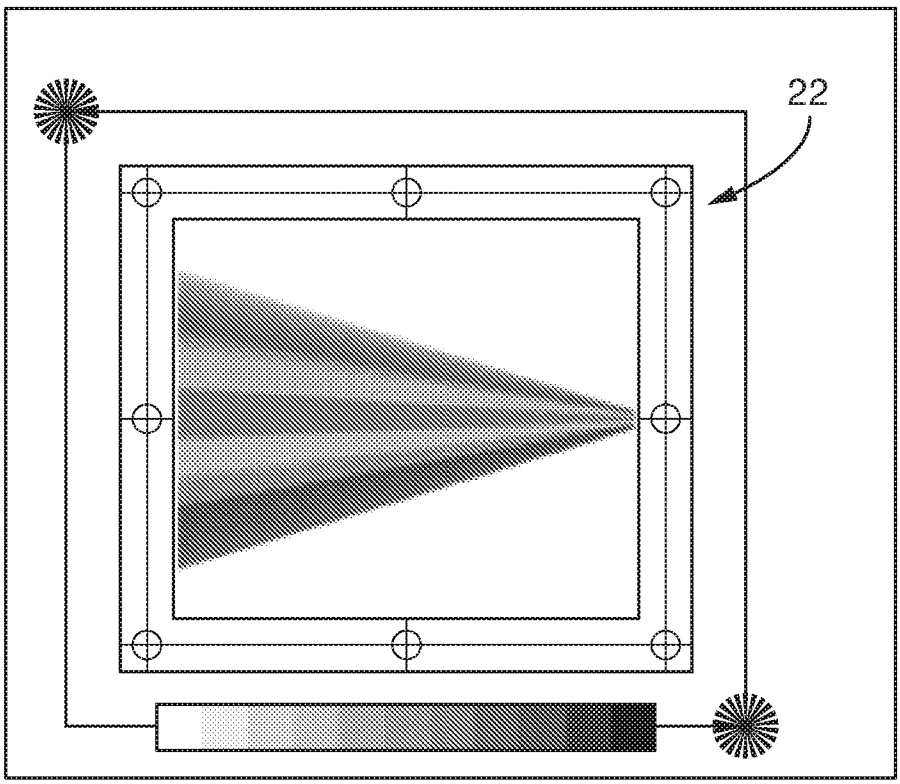
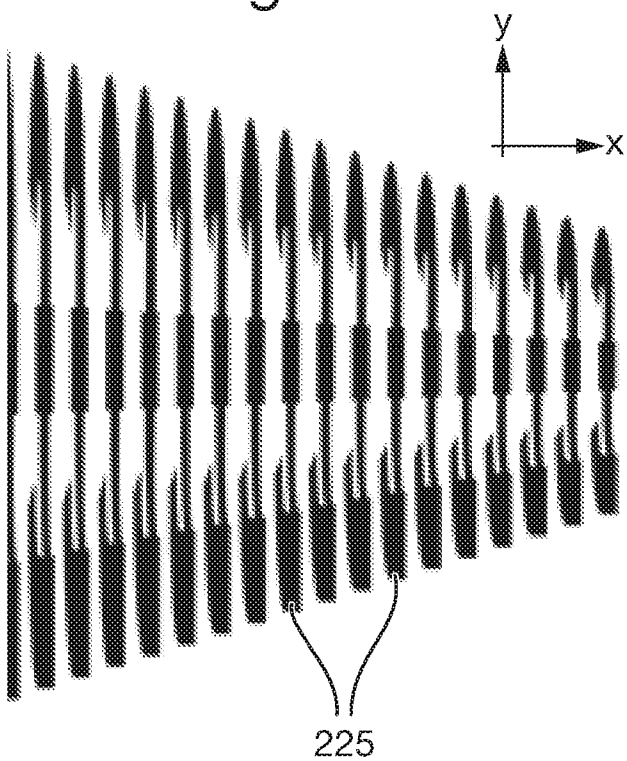


Fig. 14b



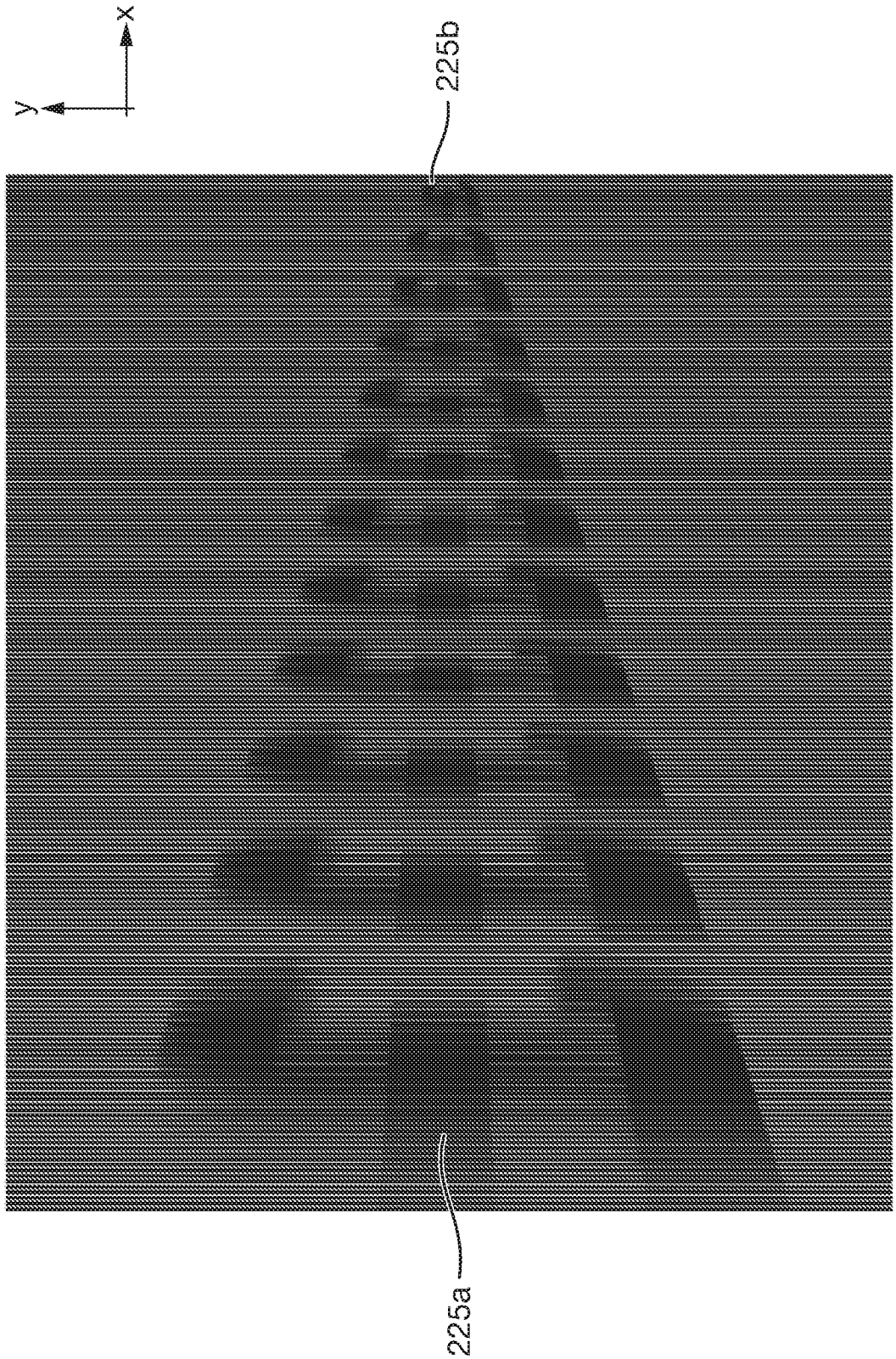


Fig. 15

Fig. 16

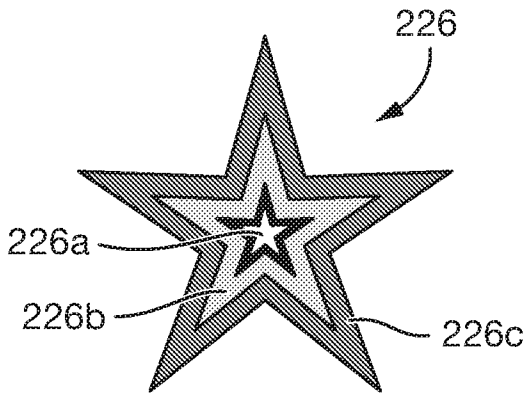


Fig. 17

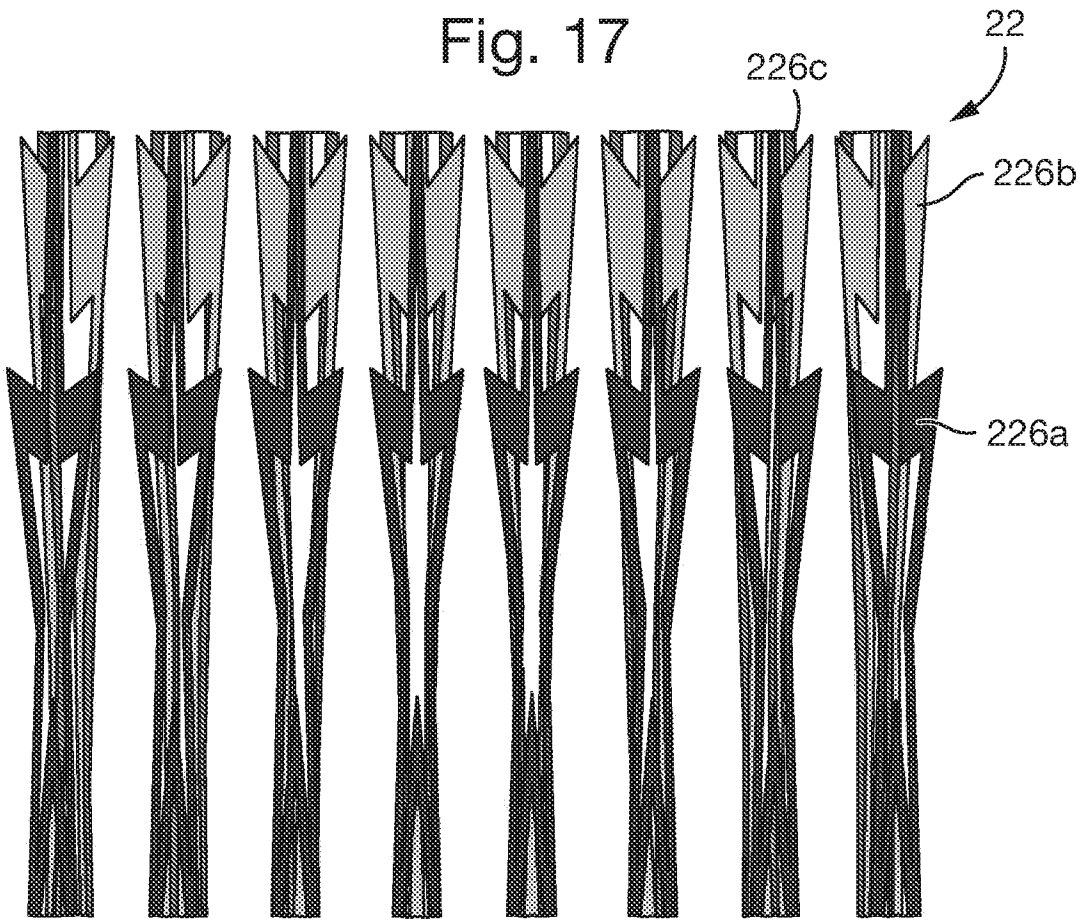


Fig. 18a

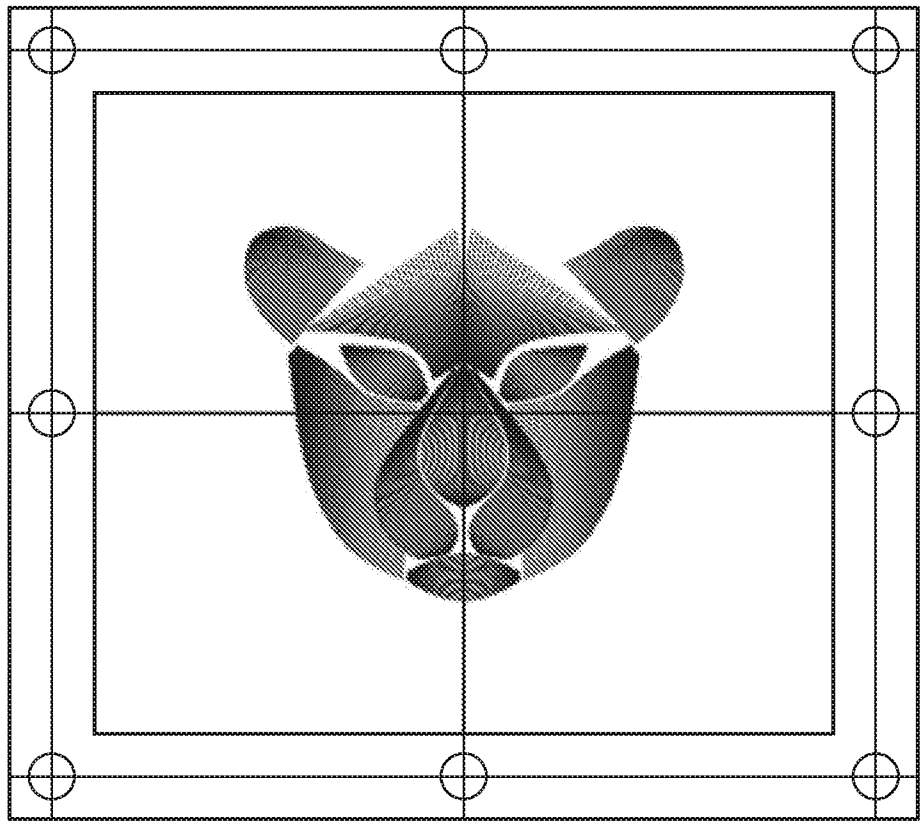


Fig. 18b

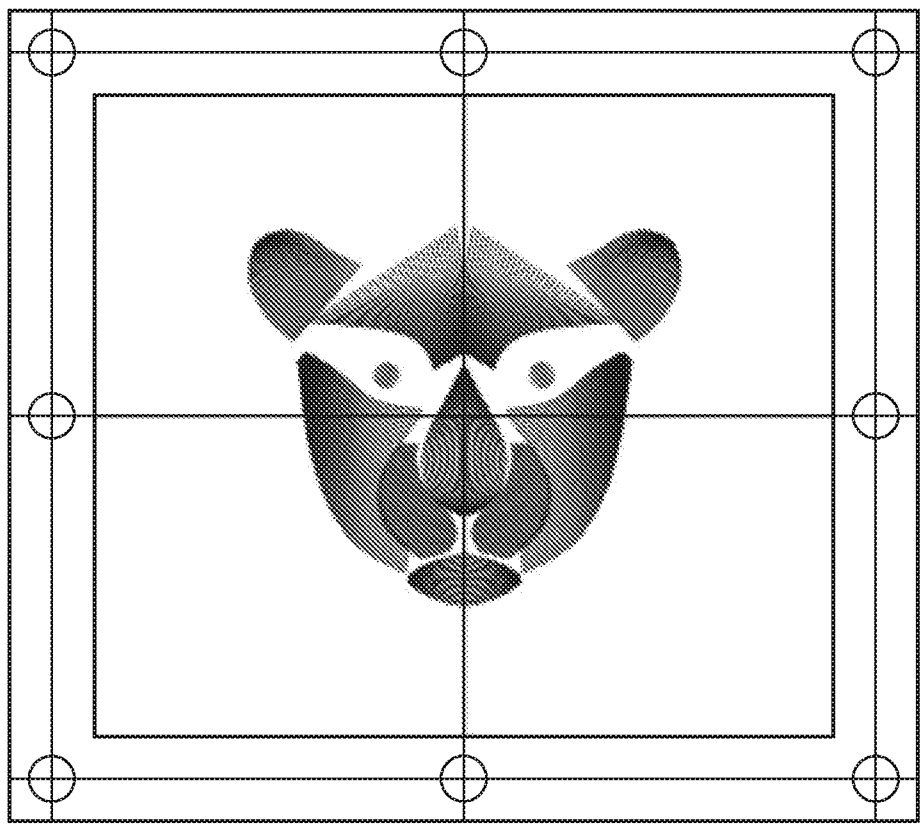


Fig. 19