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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
27 November 2014 (27.11.2014)

WIPO | PCT

(10) International Publication Number
WO 2014/186837 Al

(51) International Patent Classification:
B42D 25/328 (2014.01) *B42D 25/40* (2014.01)

(21) International Application Number:
PCT/AU20 14/050041

(22) International Filing Date:
16 May 2014 (16.05.2014)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
2013 100685 21 May 2013 (21.05.2013) AU
2013901803 21 May 2013 (21.05.2013) AU

(71) Applicant: INNOVIA SECURITY PTY LTD [AU/AU]; Potter Street, Craigieburn, Victoria 3064 (AU).

(72) Inventor: LEE, Robert Arthur; c/o Innovia Security Pty Ltd, Potter Street, Craigieburn, Victoria 3064 (AU).

(74) Agent: WATERMARK PATENT AND TRADE MARKS ATTORNEYS; Level 2, 302 Burwood Road, Hawthorn, Victoria 3122 (AU).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available):* AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, 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, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

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

(54) **Title:** OPTICAL DEVICE INCLUDING VERTICAL PDCELS

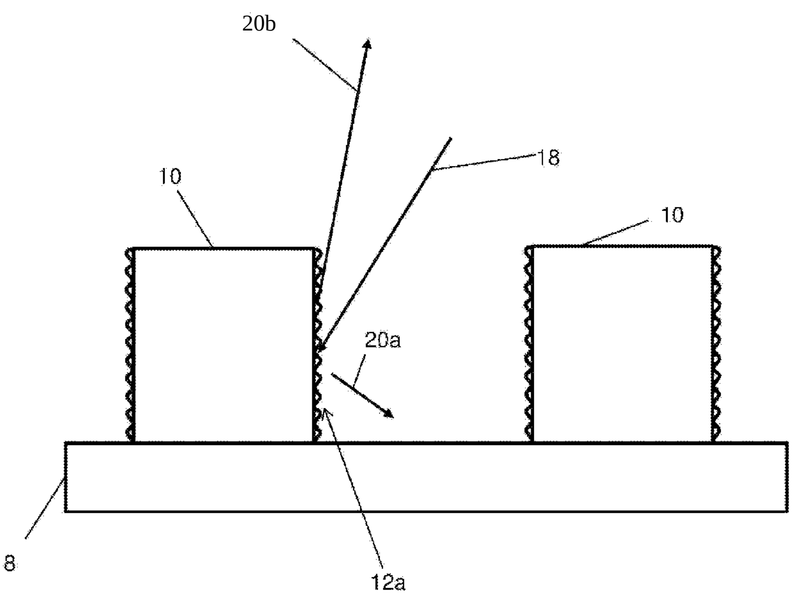


Figure 4

(57) Abstract: An optical device, preferably a security device, and a method for production thereof, said optical device including a substrate and a plurality of vertical pixels, wherein each vertical pixel is defined by a structure including at least one vertical surface extending from a first side of the substrate, preferably four vertical surfaces defining the sides of a rectangular cuboid, wherein the at least one vertical surface includes a vertical grating, wherein the, or each, vertical grating includes a plurality of longitudinally extending grating elements extending parallel to the first side of the substrate.

WO 2014/186837 A1

OPTICAL DEVICE INCLUDING VERTICAL PIXELS

FIELD OF THE INVENTION

[0001] The invention generally relates to optical devices.

BACKGROUND TO THE INVENTION

[0002] It is well known that many of the world's banknotes, as well as other security documents, carry optical devices which produce images that vary with angle of view of the device or angle of illumination by an external light source. Because the image on the device varies in this way, it cannot be copied by conventional photographic, computer scanning or other reprographic printing technologies. The incorporation of such optically variable devices (OVDs) into security documents therefore acts as a deterrent against counterfeiting of the document.

[0003] A common basis for OVD features used on banknotes and other security documents is the inclusion of diffractive structures, such as diffractive optical devices and holograms. Such structures consist of complex patterns of finely engraved grooves which interact with the incoming light to produce images via the optical mechanism of diffraction. Such devices are more difficult to counterfeit, as the underlying structures cannot be copied using the conventional techniques noted above.

[0004] Nevertheless, over recent years as counterfeiting groups have become better organised and more technically competent, the ability to reproduce diffraction based effects has increased. For example, diffractive optical devices and holograms formed through embossing processes can be copied through mechanical copying, or by simple contact copying.

[0005] As diffractive based security devices are becoming more common, it is becoming more difficult to produce a new visual effect which is sufficiently different to what is known to elicit curiosity from the general public, which then results in authentication due to the visual inspection.

SUMMARY OF THE INVENTION

[0006] According to a first aspect of the present invention, there is provided an optical device including a substrate and a plurality of vertical pixels, wherein each vertical pixel is defined by a structure including at least one vertical surface extending from a first side of the substrate, wherein the at least one vertical surface includes a vertical grating, wherein the, or each, vertical grating includes a plurality of longitudinally extending grating elements extending parallel to the first side of the substrate,

[0007] Preferably, each vertical pixel includes a top surface parallel, or substantially parallel, to the first side, and wherein the top surface includes a secondary optical feature. The secondary optical feature may be a diffractive feature, for example a hologram. Alternatively, the secondary optical feature may be a non-diffractive feature. The secondary optical feature of each vertical pixel may correspond to a component of a composite secondary optical feature.

[0008] Preferably, each vertical pixel includes four vertical surfaces, and defines a rectangular cuboid.

[0009] Preferably, the plurality of vertical pixels is configured to define at least one image, wherein each vertical pixel contributes to the image through diffraction off at least one vertical surface. The plurality of vertical pixels may define one image, and each vertical grating of the, or each, vertical surface of each vertical pixel may have the same structure. Alternatively, the plurality of vertical pixels may define two or more images, and each vertical pixel may be uniquely associated with one image, and each image may be distinguished by colour when the two or more images are viewed from a common viewing position. The two or more images may be overlapping. Alternatively, the two or more images may be located in separate regions of the substrate.

[0010] Preferably, the vertical pixels are arranged in a regular two-dimensional arrangement on the first side.

[0011] Preferably, the vertical pixels are metallised.

[0012] Preferably, each vertical pixel has an associated brightness. The brightness of each vertical pixel may be determined by the surface area of the vertical pixel.

[0013] Preferably, the vertical pixels are formed from an embossed radiation curable ink.

[0014] The optical device may be a security device.

[0015] According to a second aspect of the present invention, there is provided a security document including an optical device according to the first aspect.

[0016] Preferably, the security document includes a security document substrate. The substrate of the optical device may correspond to a region of the security document substrate. The security document may include first and second opacifying layers. The security document may be a banknote.

[0017] According to a third aspect of the present invention, there is provided a method for forming an optical device according to the first aspect, including the steps of: applying a radiation curable ink to a side of a substrate; embossing the radiation curable ink using a shim configured for forming a structure corresponding to the arrangement of the plurality of vertical pixels; and curing the radiation curable ink. The embossing step and curing step may be performed simultaneously.

[0018] According to a fourth aspect of the present invention, there is provided a shim for forming an optical device through embossing, the shim including a base and a surface profile including recesses configured for forming a corresponding vertical pixel arrangement in an embossable material. The shim may be configured for forming the optical device of the first aspect.

[0019] According to a fifth aspect of the present invention, there is provided a method for producing a shim for forming an optical device through embossing, the optica! device including a first arrangement of vertical pixels associated with a first image, each including a first vertical grating, wherein the method includes the steps of: applying a first mask to a surface of a silicon substrate, the first mask including an arrangement of first apertures; creating an arrangement of recesses corresponding to inverses of the vertical pixels using an etching process; and electroplating the surface of the silicon substrate.

[0020] Preferably, the arrangement of apertures of the first mask corresponds to the first arrangement of vertical pixels on the optical device.

[0021] Preferably, the optical device includes a second arrangement of vertical pixels associated with a second image each including a second vertical grating, wherein the first image and the second image are configured to appear different when viewed from a common predefined viewing position, and wherein the method includes the further steps of: applying a second mask to the surface of the silicon substrate after the etching process utilising the first mask, the second mask including an arrangement of second apertures; creating an arrangement of second recesses corresponding to an inverse of the second arrangement of vertical pixels using a further etching process. Preferably, the first and second recesses do not overlap.

[0022] Preferably, the etching process or processes correspondfs) to Bosch etching process(es).

[0023] Preferably, the etching process or processes correspond to repeated cycles of an etching step followed by a passivating step. The etching step may correspond to application of a SF_6 plasma. The passivating step may correspond to application of a C_4F_8 plasma. The method may include a cycle time corresponding to the time for one etching step and one passivating step, and the cycle time may determine the grating spacing of the resulting vertical gratings.

Security Document or Token

[0024] As used herein the term security documents and tokens includes all types of documents and tokens of value and identification documents including, but not limited to the following: items of currency such as banknotes and coins, credit cards, cheques, passports, identity cards, securities and share certificates, driver's licenses, deeds of title, travel documents such as airline and train tickets, entrance cards and tickets, birth, death and marriage certificates, and academic transcripts.

[0025] The invention is particularly, but not exclusively, applicable to security documents or tokens such as banknotes or identification documents such as identity cards or passports formed from a substrate to which one or more layers of printing are applied. The diffraction gratings and optically variable devices described herein may also have application in other products, such as packaging.

Security Device or Feature

[0026] As used herein the term security device or feature includes any one of a large number of security devices, elements or features intended to protect the security document or token from counterfeiting, copying, alteration or tampering. Security devices or features may be provided in or on the substrate of the security document or in or on one or more layers applied to the base substrate, and may take a wide variety of forms, such as security threads embedded in layers of the security document; security inks such as fluorescent, luminescent and phosphorescent inks, metallic inks, iridescent inks, photochromic, thermochromic, hydrochromic or piezochromic inks; printed and embossed features, including relief structures; interference layers; liquid crystal devices; lenses and lenticular structures; optically variable devices (OVDs) such as diffractive devices including diffraction gratings, holograms and diffractive optical elements (DOEs).

Substrate

[0027] As used herein, the term substrate refers to the base material from which the security document or token is formed. The base material may be paper or other fibrous material such as cellulose; a plastic or polymeric material including but not limited to polypropylene (PP), polyethylene (PE), polycarbonate (PC), polyvinyl chloride (PVC), polyethylene terephthalate (PET); or a composite material of two or more materials, such as a laminate of paper and at least one plastic material, or of two or more polymeric materials.

Transparent Windows and Half Windows

[0028] As used herein the term window refers to a transparent or translucent area in the security document compared to the substantially opaque region to which printing is applied. The window may be fully transparent so that it allows the transmission of light substantially unaffected, or it may be partly transparent or translucent partially allowing the transmission of light but without allowing objects to be seen clearly through the window area.

[0029] A window area may be formed in a polymeric security document which has at least one layer of transparent polymeric material and one or more opacifying layers applied to at least one side of a transparent polymeric substrate, by omitting least one opacifying layer in the region forming the window area. If opacifying layers are applied to both sides of a transparent substrate a fully transparent window may be formed by omitting the opacifying layers on both sides of the transparent substrate in the window area.

[0030] A partly transparent or translucent area, hereinafter referred to as a "half-window", may be formed in a polymeric security document which has opacifying layers on both sides by omitting the opacifying layers on one side only of the security document in the window area so that the "half-window" is not fully transparent, but allows some light to pass through without allowing objects to be viewed clearly through the half-window.

[0031] Alternatively, it is possible for the substrates to be formed from an substantially opaque material, such as paper or fibrous material, with an insert of transparent plastics material inserted into a cut-out, or recess in the paper or fibrous substrate to form a transparent window or a translucent half-window area.

Opacifying layers

[0032] One or more opacifying layers may be applied to a transparent substrate to increase the opacity of the security document. An opacifying layer is such that $L_T < L_0$, where L_0 is the amount of light incident on the document, and L_T is the amount of light transmitted through the document. An opacifying layer may comprise any one or more of a variety of opacifying coatings. For example, the opacifying coatings may comprise a pigment, such as titanium dioxide, dispersed within a binder or carrier of heat-activated cross-linkable polymeric material. Alternatively, a substrate of transparent plastic material could be sandwiched between opacifying layers of paper or other partially or substantially opaque material to which indicia may be subsequently printed or otherwise applied.

Diffractive Optical Elements (DOEs)

[0033] As used herein, the term diffractive optical element refers to a numerical-type diffractive optical element (DOE), Numerical-type diffractive optical elements (DOEs) rely on the mapping of complex data that reconstruct in the far field (or reconstruction plane) a two-dimensional intensity pattern. Thus, when substantially collimated light, e.g. from a point light source or a laser, is incident upon the DOE, an interference pattern is generated that produces a projected image in the reconstruction plane that is visible when a suitable viewing surface is located in the reconstruction plane, or when the DOE is viewed in transmission at the reconstruction plane. The transformation between the two planes can be approximated by a fast Fourier transform (FFT). Thus, complex data including amplitude and phase information has to be physically encoded in the micro-structure of the DOE. This DOE data can be calculated by performing an inverse FFT transformation of the desired reconstruction (i.e. the desired intensity pattern in the far field).

[0034] DOEs are sometimes referred to as computer-generated holograms, but they differ from other types of holograms, such as rainbow holograms, Fresnel holograms and volume reflection holograms.

Refractive index n

[0035] The refractive index of a medium n is the ratio of the speed of light in vacuum to the speed of light in the medium. The refractive index n of a lens determines the amount by which light rays reaching the lens surface will be refracted, according to Snell's law:

$$n_1 * \sin(\alpha) = n * \sin(\theta),$$

where α is the angle between an incident ray and the normal at the point of incidence at the lens surface, Θ is the angle between the refracted ray and the normal at the point of incidence, and n_1 is the refractive index of air (as an approximation n_1 may be taken to be 1).

Embossable Radiation Curable Ink

[0036] The term embossable radiation curable ink used herein refers to any ink, lacquer or other coating which may be applied to the substrate in a printing process, and which can be embossed while soft to form a relief structure and cured by radiation to fix the embossed relief structure. The curing process does not take place before the radiation curable ink is embossed, but it is possible for the curing process to take place either after embossing or at substantially the same time as the embossing step. The radiation curable ink is preferabiy curable by ultraviolet (UV) radiation. Alternatively, the radiation curable ink may be cured by other forms of radiation, such as electron beams or X-rays.

[0037] The radiation curable ink is preferably a transparent or translucent ink formed from a clear resin material. Such a transparent or translucent ink is particularly suitable for printing light-transmissive security elements such as sub-wavelength gratings, transmissive diffractive gratings and lens structures.

[0038] in one particularly preferred embodiment, the transparent or translucent ink preferably comprises an acrylic based UV curable clear embossable lacquer or coating.

[0039] Such UV curable lacquers can be obtained from various manufacturers, including Kingfisher Ink Limited, product ultraviolet type UVF-203 or similar. Alternatively, the radiation curable embossable coatings may be based on other compounds, eg nitro-cellulose.

[0040] The radiation curable inks and lacquers used herein have been found to be particularly suitable for embossing microstructures, including diffractive structures such as diffraction gratings and holograms, and microlenses and lens arrays. However, they may also be embossed with larger relief structures, such as non-diffractive optically variable devices.

[0041] The ink is preferably embossed and cured by ultraviolet (UV) radiation at substantially the same time. In a particularly preferred embodiment, the radiation curable ink is applied and embossed at substantially the same time in a Gravure printing process.

[0042] Preferably, in order to be suitable for Gravure printing, the radiation curable ink has a viscosity falling substantially in the range from about 20 to about

175 centipoise, and more preferably from about 30 to about 150 centipoise. The viscosity may be determined by measuring the time to drain the lacquer from a Zahn Cup #2. A sample which drains in 20 seconds has a viscosity of 30 centipoise, and a sample which drains in 63 seconds has a viscosity of 150 centipoise.

[0043] With some polymeric substrates, it may be necessary to apply an intermediate layer to the substrate before the radiation curable ink is applied to improve the adhesion of the embossed structure formed by the ink to the substrate. The intermediate layer preferably comprises a primer layer, and more preferably the primer layer includes a polyethylene imine. The primer layer may also include a cross-linker, for example a multi-functional isocyanate. Examples of other primers suitable for use in the invention include: hydroxyl terminated polymers; hydroxyl terminated polyester based co-polymers; cross-linked or uncross-linked hydroxylated aerylates; polyurethanes; and UV curing anionic or cationic aerylates. Examples of suitable cross-linkers include: isoeyanates; polyaziridines; zirconium complexes; aluminium acetylacetone; melamines; and carbodi-imides.

Metallic Nanoparticle Ink

[0044] As used herein, the term metallic nanoparticle ink refers to an ink having metallic particles of an average size of less than one micron.

BRIEF DESCRIPTION OF THE DRAWINGS

[0045] Embodiments of the invention will now be described with reference to the accompanying drawings. It is to be appreciated that the embodiments are given by way of illustration only and the invention is not limited by this illustration. In the drawings:

[0046] Figure 1a shows a security document including a security device located within a half-window region;

[0047] Figure 1b shows a security document including a security device located within a window region;

[0048] Figure 2 shows a security device including an arrangement of vertical pixels;

[0049] Figure 3 shows a vertical pixel;

[0050] Figure 4 shows incident light onto, and diffracted light off, a reflective vertical grating;

[0051] Figure 5 shows a shim for forming the arrangement of vertical pixels;

[0052] Figure 6 shows the steps involved in etching, via the Bosch process, a silicon substrate;

[0053] Figure 7 shows an image formed by an arrangement of vertical pixels;

[0054] Figure 8 shows two images formed by two arrangements of vertical pixels;

[0055] Figure 9 shows different sizes of vertical pixels;

[0056] Figure 10 shows a radiation curable ink applied to a substrate;

[0057] Figure 11 shows a transmission vertical pixel;

[0058] Figure 12 shows an colour image based vertical pixel arrangement;

[0059] Figure 13 shows vertical pixels including secondary security features located on top faces of the vertical pixels;

[0060] Figure 14 shows vertical pixels including diffraction gratings as secondary security features;

[0061] Figure 15 shows a substrate including vertical pixels configured to interface with a light guide.

DESCRIPTION OF PREFERRED EMBODIMENT

[0062] Referring to Figures 1a and 1b, there is shown a security document 2 including an optical device 4 and an optional further security feature 6. The security document 2 includes a substrate 8. The optical device 4 also includes a substrate 8, which in the present case is the same substrate 8 as the security document 2, though this is not a requirement. The optical device 4 can provide a security function, such that the optical device 4 acts as a security device for providing means for determining the authenticity of the security document 2. Also shown are first and second opacifying layers 7a, 7b.

[0063] In Figure 1a, the optical device 4 is shown located in a half-window region of the security document 2, such that the second opacifying layer 7b covers the optical device 4. Alternatively, as shown in Figure 1b, the optical device 4 can be located in a window region of the security document 2, wherein the second opacifying layer 7b is absent in the region of the optical device 4. Though the opacifying layers 7a, 7b are shown contiguous with the optica! device 4, this is not necessary. For example, there may be a gap between the edge of the optical device 4 and the edge of the opacifying regions 7a, 7b. Optional further security features 6 include diffractive optical devices, holograms, microlens based optical variable devices, windows, and any other suitable security feature(s), and can be located within window or half-window regions of the substrate B as necessary and/or desired.

[0064] Referring now to Figure 2, the optical device 4 includes an arrangement of optical elements 10, herein referred to as vertical pixels 10, formed on a side of the substrate 8. The vertical pixels 10 correspond to structures extending from the side of the substrate 8. The centre-to-centre spacing between adjacent vertical pixels 10 can be substantially twice the height of vertical pixel 10. Also, the height of each vertical pixel 10 can be substantially the same as the width of each vertical pixel 10. In an embodiment, the vertical pixels 10 can have a height of 15 microns and a width of 15 microns. In this case, the centre-to-centre spacing between adjacent vertical pixels 10 is 30 microns.

[0065] A more detailed view of a vertical pixel 10 is shown in Figure 3. The vertical pixel 10 includes vertical, or at least substantially vertical, surfaces 12 (specific vertical surfaces 12 will herein be referred to using a letter, for example 12a). Each vertical pixel 10 also includes a top surface 13, parallel, or at least substantially parallel, to the side of the substrate S. "Surface area" as used herein in relation to a vertical pixel refers to the surface area of the top surface 13 of the vertical pixel.

[0066] Each vertical surface 12 further includes grating elements 14. The grating elements 14 are longitudinally extending, with the longitudinal direction being parallel to the surface of the substrate 8. The grating elements 14 of a particular vertical surface 12 form a vertical grating, wherein the normal of the vertical grating is perpendicular to the normal of the side of the substrate 8. The vertical gratings can be transmissive or reflective. The term "vertical grating" is used herein to distinguish from conventional diffraction gratings (herein referred to as "planar diffraction gratings") formed by an arrangement of grating structures in a plane parallel to a plane of the substrate 8. It is noted that the shape of the vertical pixels 10 is not limited to cuboid structures, and can include other structures which incorporate vertical, or at least substantially vertical, faces 12. Examples of such alternate structures include: cylindrical-shaped pillars; elliptical-shaped pillars; and other shapes with a number of vertical surfaces 12 different to four.

[0067] Figure 4 shows the effect of the grating on incident light 18, for reflective vertical gratings. The incident light 18 is diffracted by the vertical grating of a vertical surface 12a. Considering the +1 (20a) and -1 (20b) diffraction orders (which are typically the brightest diffraction orders) for a particular wavelength, the +1 order 20a is directed towards the side of the substrate 8, and may be reflected. However, overall, the +1 order 20a is supressed due to interactions with the substrate 8 and/or vertical pixels 10. The -1 order 20b is diffracted directly away from the substrate 8, and is therefore directly viewable. The result is that the -1 order 20b dominates the appearance of the vertical pixel 10. It is noted that the labelling of "+" and "-" orders 20a, 20b is arbitrary, and simply used to indicate corresponding diffraction orders on opposite sides of the incident light ray. In general, for a fixed vertical pixel 10 height, an increase in the spacing between adjacent vertical pixels 10 will lead to an increase in the range of viewing angles associated with the optical device 4.

[0068] Advantageously, the viewable diffraction order (i.e. -1 (20b) in Figure 4) is viewable at a shallow angle when compared to planar diffraction gratings. Furthermore, the suppression of the other diffraction order (i.e. +1 (20a) in Figure 4) can be advantageous and furthermore can provide an unexpected and memorable effect. Also, it may be advantageous to provide vertical surfaces 12 that are sufficiently vertical to eliminate, or at least severely impede, attempts at reproducing the surface structure of the optical device 4.

[0069] Referring to Figure 5, the optical device 4 can be manufactured by embossing the substrate 8, or a material applied to the substrate 8, with an appropriate shim 22. The shim 22 includes a base 33 (for example, siiicon), which has a surface profile corresponding to the inverse, or negative, of the desired optical device 4 surface profile, and therefore the shim 22 includes recesses 35 including vertical recess walls 34, the surface of the recess walls 34 including longitudinally extending recess grating elements 36 extending parallel to the surface of the shim 22.

[0070] Referring to Figure 6, the shim 22 can be produced by utilising the Bosch process (also known as also known as pulsed or time-multiplexed etching), which can be used to create surface relief structures by utilising a two stage plasma etching process 24. A mask 26 is placed over a silicon substrate 28 (i.e. base 33 of Figure 5), where apertures in the mask 26 define locations for the formation of the recesses (35 of Figure 5), The apertures define the shape of the resulting vertical pixels 10 when viewed from above, for example the apertures will be square for forming vertical pixels 10 such as shown in Figure 2. The plasma etching process 24 includes repetitions of an etching step 30 followed by a passivating step 32. The etching step 30 can utilise, for example, a SF_6 plasma. The passivating step 32 can utilise, for example, a $C{+}F_8$ plasma. The passivating step 32 acts to create a fluoro-carbon film layer on the surface of the silicon substrate 28. The fluoro-carbon film layer is removed by the SF_6 ions in the subsequent etching step 30, however only by the SF¾ ions directed perpendicufarly onto the surface of the silicon substrate 28. In this way, the fluoro-carbon film remains covering the sides of the recess that is being created, and thus protects the sides of the recess from further etching. Each step 30, 32 is associated with a step time (i.e. an etching step time and a passivating step time), and the sum of the two step times is equal to the cycle time of the process.

[0071] The Bosch process results in substantially vertical surfaces including repeating undulations. The size of the undulations is proportional to the cycle time, such that longer cycle times result is larger spacing between adjacent undulations, and shorter cycle times result in smaller spacing. The undulations in the present case ultimately correspond to the recess grating elements 36, and therefore the cycle time can be adjusted to provide for required recess grating element 36 spacing. In embodiments, the cycle time is varied during the Bosch process to create variable length undulations, which can therefore ultimately be used to create vertical gratings with variable spacing between grating elements.

[0072] After the shim 22 is produced, it can be used to create a large number of security devices 4 through embossing. According b one technique, the substrate 8 of a security device has a radiation curable ink 42 applied to a first side (as shown in Figure 10). The radiation curable ink 42 is then embossed using the shim 22 and cured using radiation. The radiation curable ink 42 can be configured to shrink during curing. Advantageously, such shrinkage can allow for the shim 22 to be extracted from the radiation curable ink 42 without, or at least with minimal or reduced, damage to the shim 22 and/or the newly embossed structure.

[0073] In order to produce a reflective optical device 4 (such as that shown in Figure 4), the vertical pixels 10 can be metallised using known techniques. In an alternative embodiment, a transmission security devices 4 (as shown in Figure 11) includes transparent vertical pixels 10, such that one order can propagate through the substrate 8 and therefore be visible on the opposite side of the substrate 8 to the vertical pixels.

[0074] The optical device 4 can display one or more images 38 due to the arrangement and configuration of the vertical pixels 10 (herein, specific images are labelled by lowercase letters, for example 38a, 38b). Referring to Figure 7, a required image 38a (in this case, an uppercase 'A') can be formed by using an appropriate mask 26 for the Bosch process. Each vertical pixel 10 corresponds to recesses 35 formed during the same Bosch process, and therefore the vertical faces 12 of each vertical pixel 10 define the same, or at least substantially the same, grating. Therefore, each vertical pixel 10 will diffract the same, or substantially the same, wavelength(s) when the optical device 4 is viewed at a particular angle, and each vertical pixel 10 is therefore associated with the image 38a.

[0075] Referring to Figure 8, two or more (in this case, two) required images 38a, 38b can be formed, each image 38a, 38b uniquely associated with a set of vertical pixels 10, wherein each set of vertical pixels 10 is formed, in sequence, using a different mask 26. Each image 38a, 38b is associated with a different spacing between grating elements 14 of the associated vertical pixels 10, such that the wavelength(s) viewable at a predefined viewing position are different for each image 38a, 38b. Thus, the "B" image 38b appears as a different colour to the "A" image 38a when viewed from a common predefined viewing position.

[0076] In embodiments, such as those illustrated in Figures 7 and 8, each vertical pixel 10 is of substantially the same surface area, resulting in substantially the same apparent brightness of each of the vertical pixels 10 (in particular, vertical pixels 10 with the same, or substantially the same, grating spacing).

[0077] Referring to Figure 9, the surface area of the vertical pixels 10 can be varied in order to provide for different brightness vertical pixels 10. Figure 9 shows an example including sixteen vertical pixel sizes 40, ranging from zero microns (40a) to 60 microns (40p), in four micron steps. It can be preferable to arrange vertical pixels 10 into a grid (as shown), so that the centre position of each vertical pixel 10 is located in a regular position, even with variations in the size of the vertical pixels 10. The size of the vertical pixels 10 is simply determined by the associated aperture size of the mask 26. it can be that the spacing between a vertical surface 12 of a vertical pixel 10 and the adjacent vertical surface 12 of an adjacent vertical pixel 10 is constant despite changes in vertical pixel 10 size. Alternatively, the centre-to-centre spacing between adjacent vertical pixels 10 is constant. In this case, there can preferably be a minimum spacing between a vertical surface 12 of a vertical pixel 10 and the adjacent vertical surface 12 of an adjacent vertical pixel 10.

[0078] An implementation of the optical device 4 is shown in Figure 12, including three monochrome images, each monochrome image uniquely associated with a plurality of vertical pixels 10a, 10b, 10c (respectively). The vertical pixels 10a, 10b, 10c are interspersed in such a way as to form groups 52, each group 52 including one of each vertical pixel 10a, 10b, 10c. Each vertical pixel 10a, 10b, 10c is associated with a brightness, wherein the surface area of the vertical pixel 10a, 10b, 10c is proportional to the required brightness, as previously described with reference to Figure 9. Each group 52 can correspond to a pixel of a colour image, wherein the colour image is effectively a composite of the three monochrome images, with the colour of the pixel determined by the relative brightness of each vertical pixel 10a, 10b, 10c within the particular group 52. In an example of the implementation, there are eight levels of brightness selectable for each vertical pixel 10a, 10b, 10c, thereby providing for 512 different colours. Each vertical pixel 10a, 10b, 10c can be assigned a primary colour (for example, red 10a, green 10b, and blue 10c) based on the monochrome image associated with the vertical pixel 10a, 10b, 10c, wherein each colour may be defined by the appearance of the vertical pixels 10a, 10b, 10c at a common predefined viewing position.

[0079] Referring to Figure 13, the top surface 13 of each vertical pixel 10 is configured to provide a secondary visual effect. The secondary visual effect can be an optically variable effect or an optically invariable effect. An example of an optically variable secondary visual effect is a holographic effect or diffractive optical device effect. Such secondary visual effects can require an arrangement of diffractive structures 46 on the top surface 13 of each vertical pixel 10, as shown in Figure 14. Though each diffractive structure 46 arrangement of each vertical pixel 10 top surface 13 is shown as the same, this is for illustration purposes and it is understood that the arrangements may vary between vertical pixels 10. An example of an optically invariable secondary visual effect is a diffuse scattering and/or micrographic effect and/or printed image. Such an effect can result from images formed from ink printed onto the top face 13 of the vertical pixels 10.

[0080] Referring to Figure 15, in an embodiment, the diffractive order 20a directed towards the substrate 8 provides input light for a waveguide 48 incorporated into the substrate 8.

[0081] Further modifications and improvements may be made without departing from the scope of the present invention. For example, the heights of different vertical pixels 10 can vary. Another modification incorporates nonparallel top surfaces to all or a selection of the vertical pixels. For example, the top surface may be configured to be slanted.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. An optical device, preferably a security device, including a substrate and a plurality of vertical pixels, wherein each vertical pixel is defined by a structure including at least one vertical surface extending from a first side of the substrate, preferably four vertical surfaces defining the sides of a rectangular cuboid, wherein the at least one vertical surface includes a vertical grating, wherein the, or each, vertical grating includes a plurality of longitudinally extending grating elements extending parallel to the first side of the substrate,

2. An optical device as claimed in claim 1, wherein each vertical pixel includes a top surface parallel, or substantially parallel, to the first side, and wherein the top surface includes a secondary optical feature, wherein the secondary optical feature is a diffractive feature, such as a hologram, or a non-diffractive feature.

3. An optical device as claimed in claim 2, wherein the secondary optical feature of each vertical pixel corresponds to a component of a composite secondary optical feature

4. An optical device as claimed in claim 1, wherein the plurality of vertical pixels is configured to define at least one image, wherein each vertical pixel contributes to the image through diffraction off at least one vertical surface, wherein each vertical grating of the, or each, vertical surface of each vertical pixel has the same structure.

5. An optical device as claimed in claim 1, wherein the plurality of vertical pixels is configured to define at two or more images, wherein each vertical pixel contributes to the image through diffraction off at least one vertical surface, wherein each vertical pixel is uniquely associated with one image, and wherein

each image is distinguished by colour when the two or more images are viewed from a common predefined viewing position.

6. An optical device as claimed in claim 1, wherein the vertical pixels are arranged in a regular two-dimensional arrangement on the first side.

7. An optical device as claimed in claim 1, wherein the vertical pixels are metallised.

8. An optical device as claimed in claim 1, wherein each vertical pixel has an associated brightness, preferably determined by the surface area of the vertical pixel.

9. An optical device as claimed in claim 1, wherein the vertical pixels are formed from an embossed radiation curable ink.

10. A security document, preferably a banknote, including an optical device according to any one of the previous claims.

11. A security document as claimed in claim 10, including a security document substrate, the substrate of the optical device corresponds to a region of the security document substrate, the security document substrate preferably including first and second opacifying layers.

12. A method for forming an optical device according to any one of claims 1 to 9, including the steps of: applying a radiation curable ink to a side of a substrate; embossing the radiation curable ink using a shim configured for forming a structure corresponding to the arrangement of the plurality of vertical pixels; and curing the radiation curable ink, preferably wherein the embossing step and curing step are performed simultaneously.

13. A shim for forming an optical device through embossing, the shim including a base and a surface profile including recesses, and configured for forming a corresponding vertical pixel arrangement in an embossable material.

14. A shim as claimed in claim 13, wherein the shim is configured for forming the optical device of any one of claims 1 to 9.

15. A method for producing a shim for forming an optical device, preferably a security device, through embossing, the optical device including a first arrangement of vertical pixels associated with a first image, each including a first vertical grating, wherein the method includes the steps of: applying a first mask to a surface of a silicon substrate, the first mask including an arrangement of first apertures: creating an arrangement of recesses corresponding to inverses of the vertical pixels using an etching process; and electroplating the surface of the silicon substrate.

16. A method as claimed in claim 15, wherein the arrangement of apertures of the first mask corresponds to the first arrangement of vertical pixels on the optical device.

17. A method as claimed in any one of claims 15 and 16, wherein the optical device includes a second arrangement of vertical pixels associated with a second image each including a second vertical grating, wherein the first image and the second image are configured to appear different when viewed from a common predefined viewing position, and wherein the method includes the further steps of: applying a second mask to the surface of the substrate after the etching process utilising the first mask, the second mask including an arrangement of second apertures; creating an arrangement of second recesses, preferably not overlapping the first recesses, corresponding to an inverse of the second arrangement of vertical pixels using a further etching process.

18. A method as claimed in claim 15, wherein the etching process or processes correspond(s) to Bosch etching process(es).

19. A method as claimed in claim 18, wherein the etching process or processes correspond to repeated cycles of an etching step, preferably corresponding to the application of a SF_6 plasma, followed by a passivating step, preferably corresponding to the application of a G_4F_8 plasma.

20. A method as claimed in claim 19, including a cycle time corresponding to the time for one etching step and one passivating step, wherein the cycle time determines the grating spacing of the resulting vertical gratings.

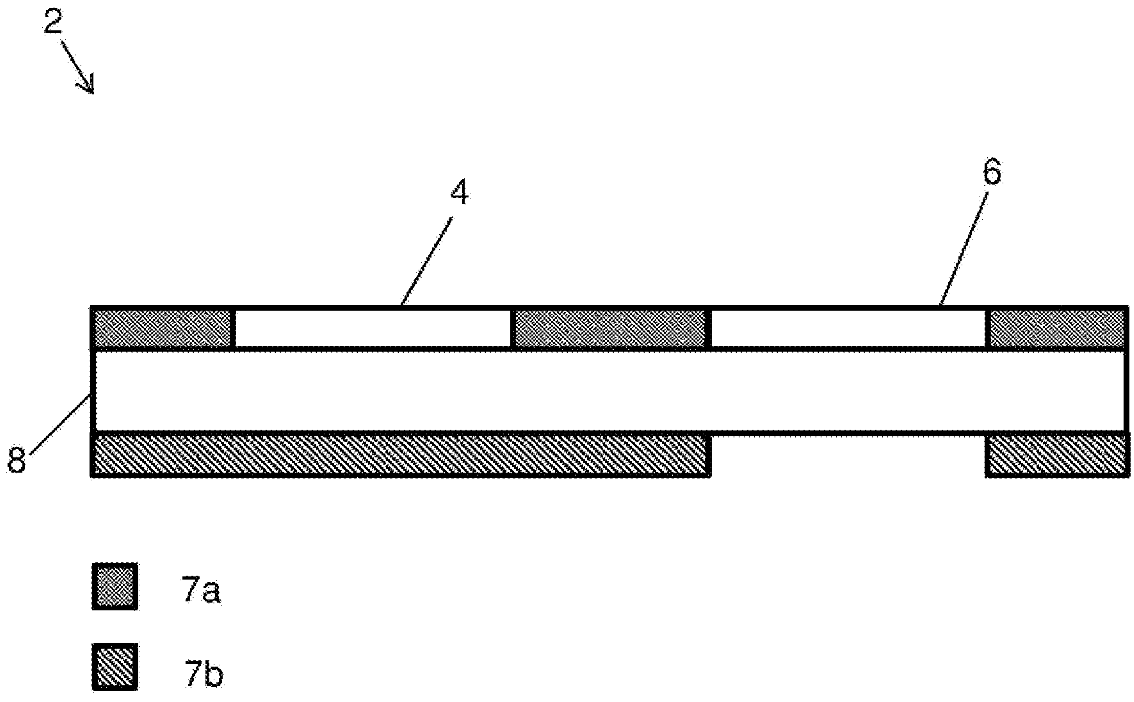


Figure 1a

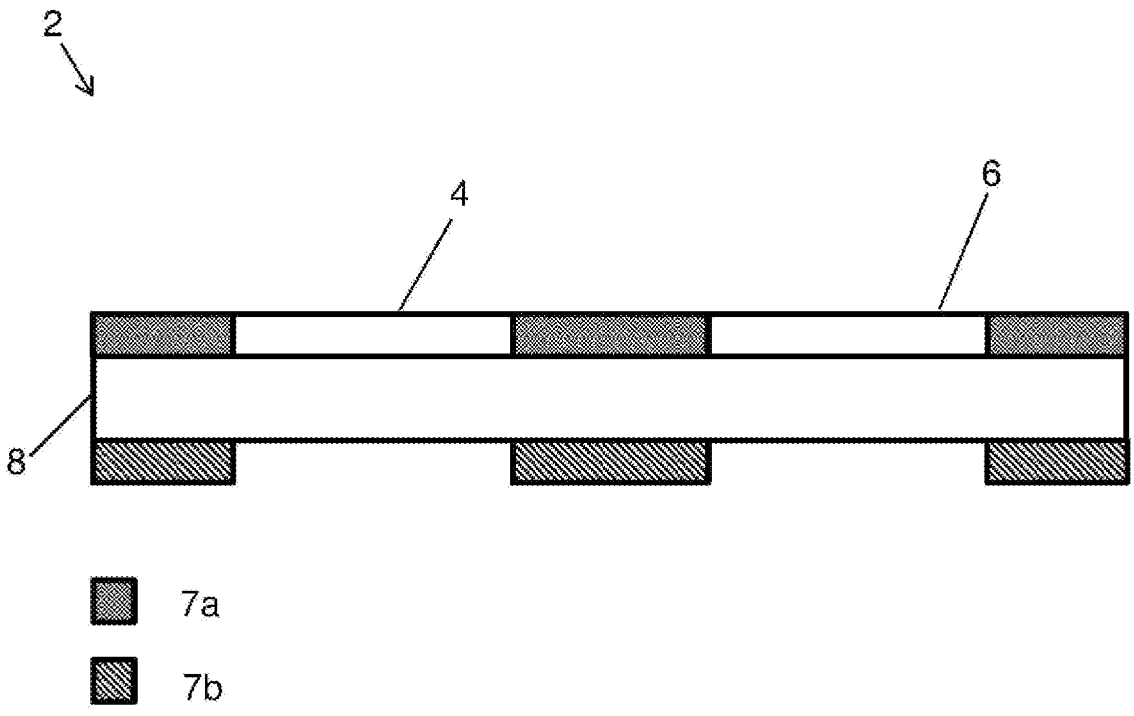


Figure 1b

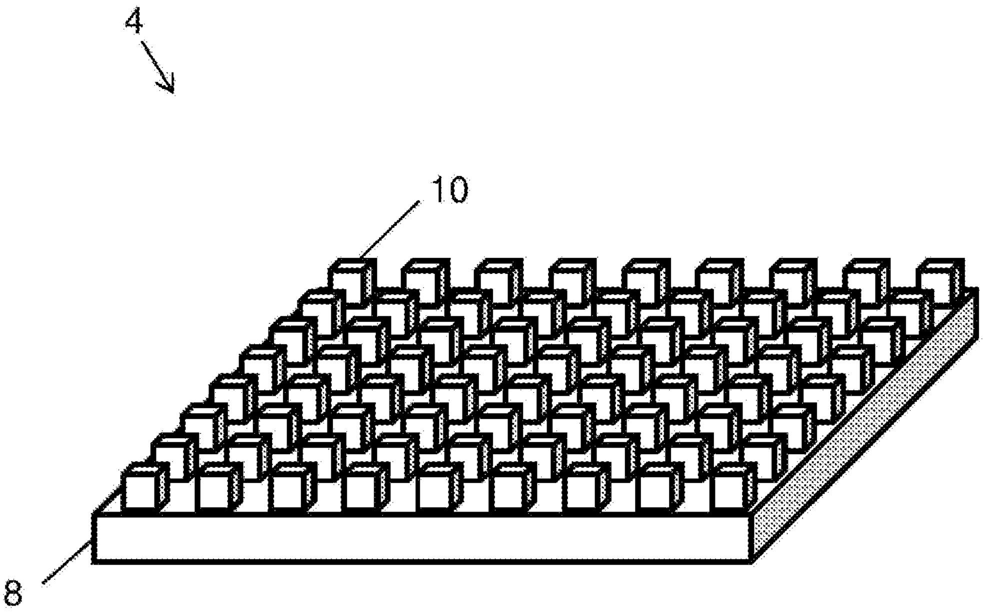


Figure 2

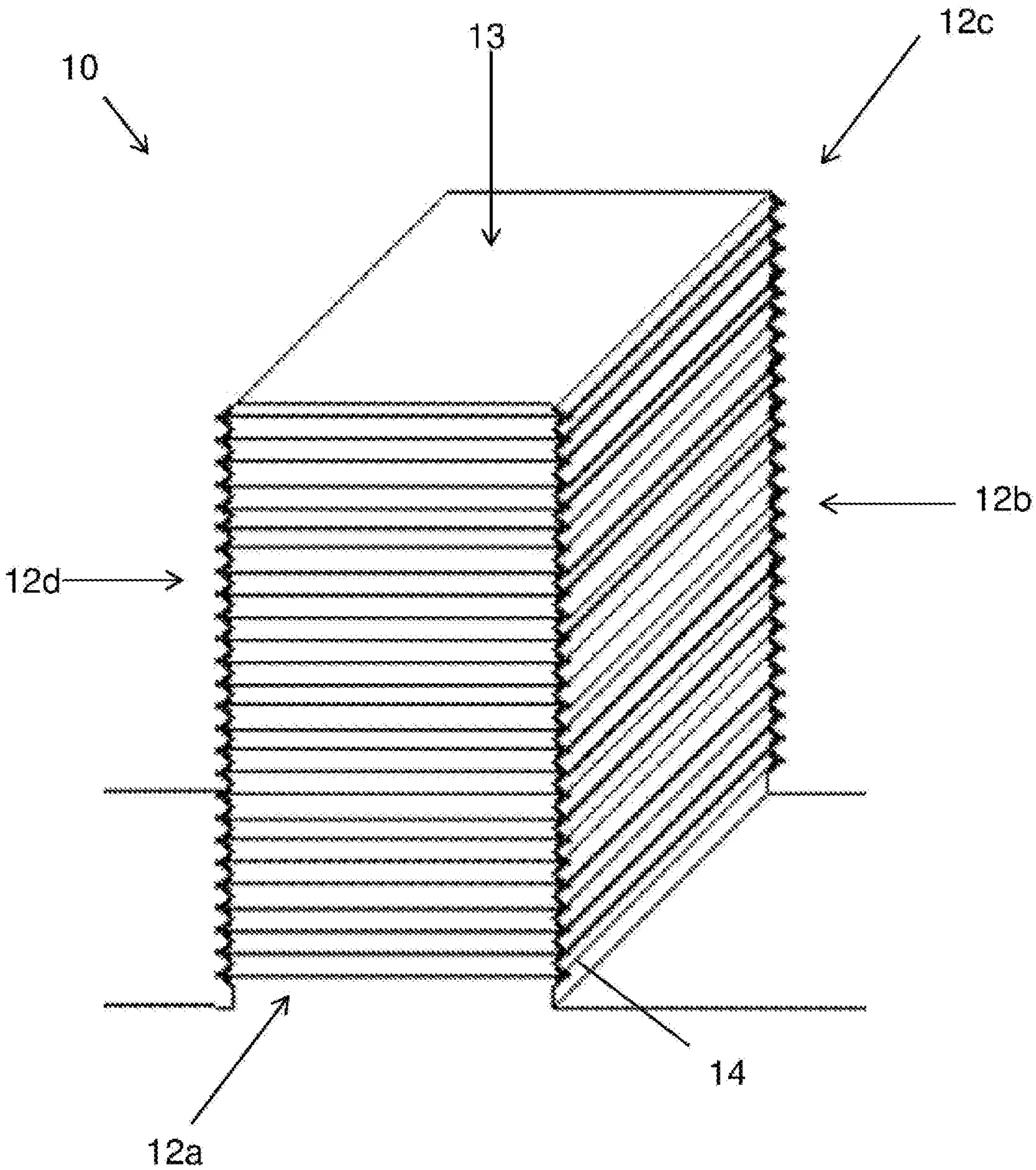


Figure 3

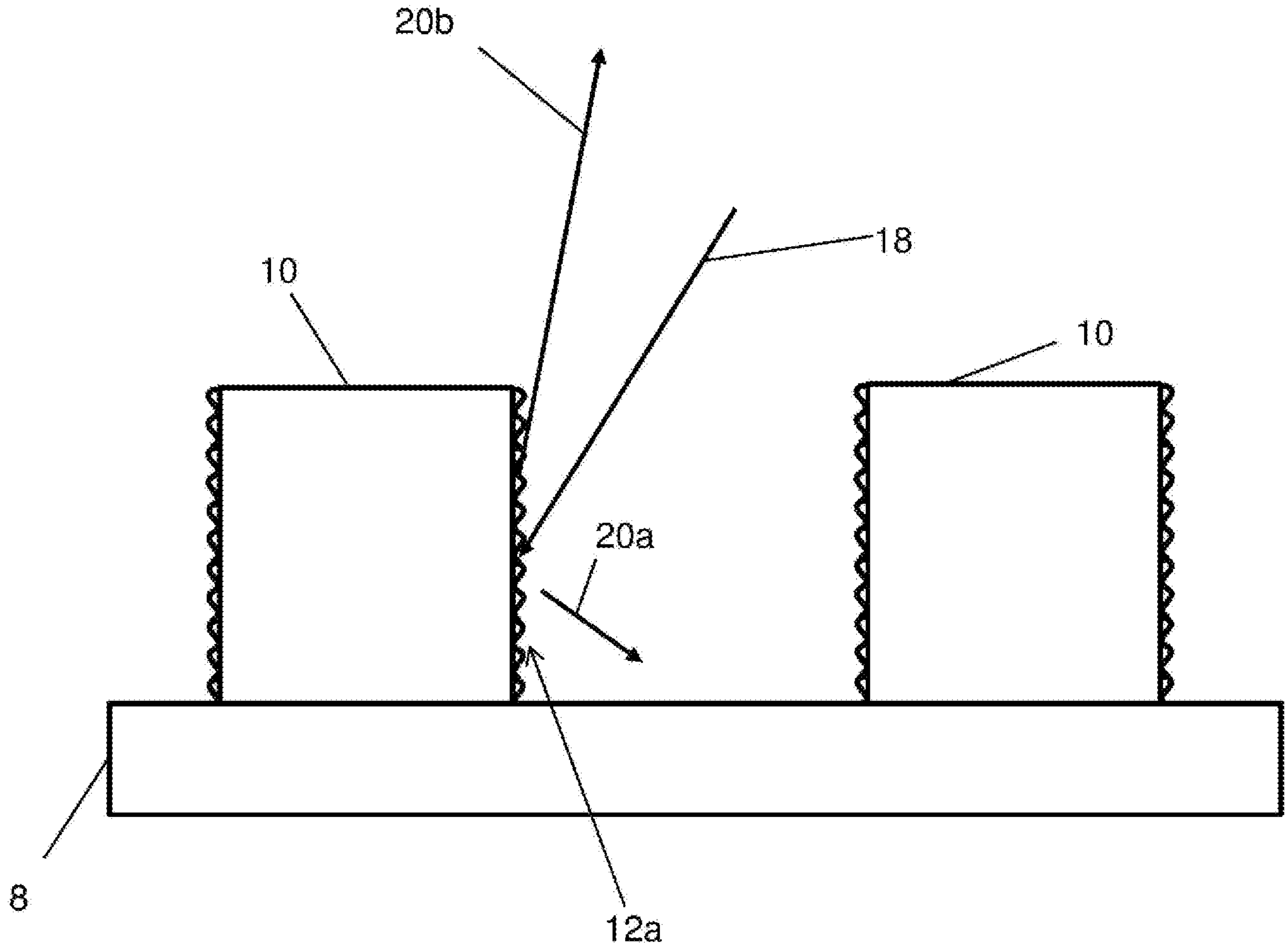


Figure 4

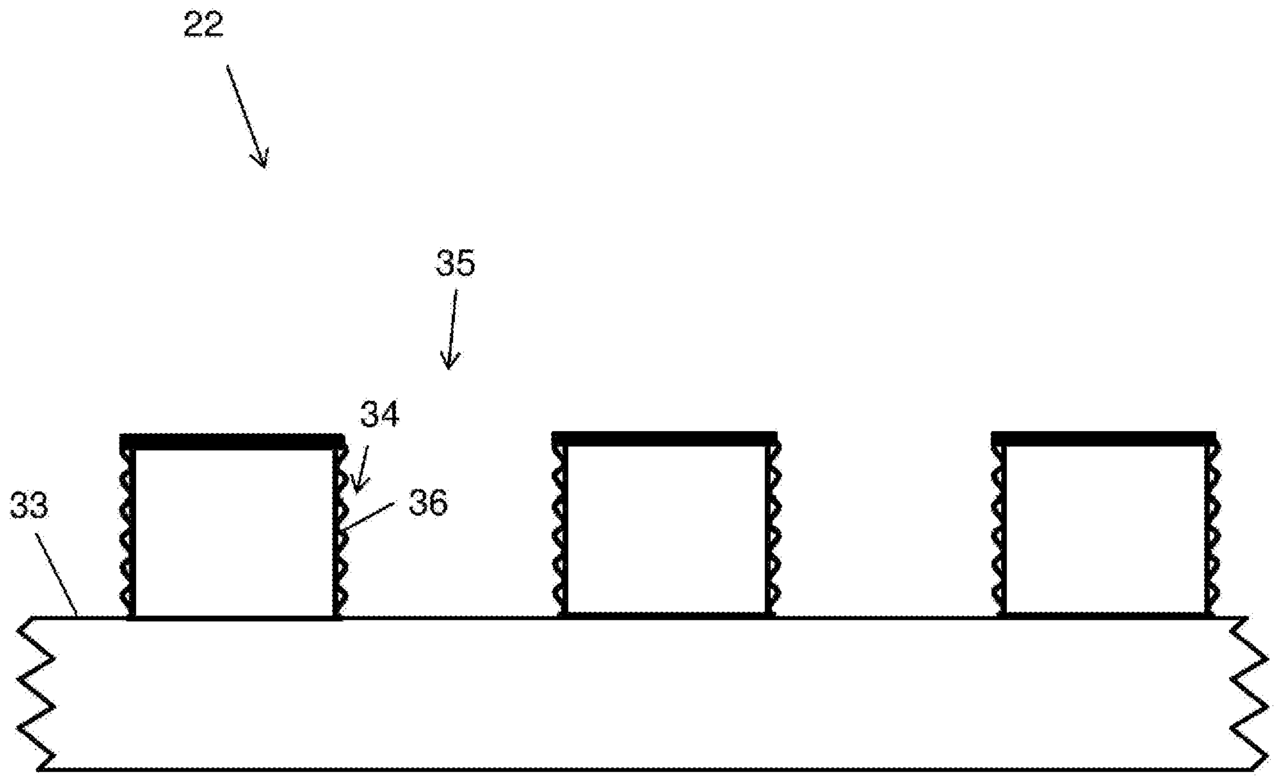


Figure 5

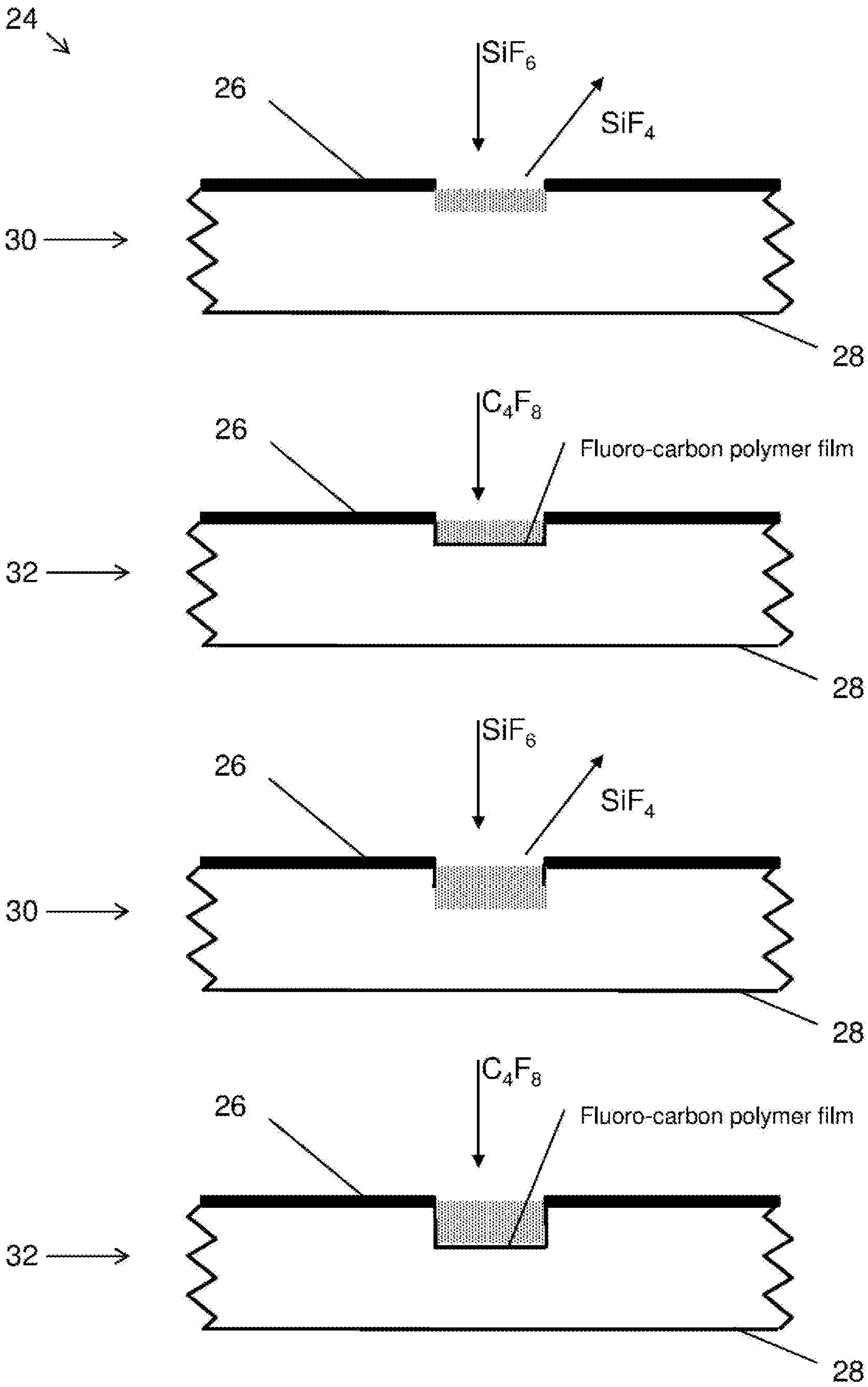

24
SiF_6
26
SiF_4
30
28
C_4F_8
26
Fluoro-carbon polymer film
32
28
SiF_6
26
SiF_4
30
28
C_4F_8
26
Fluoro-carbon polymer film
32
28

Figure 6

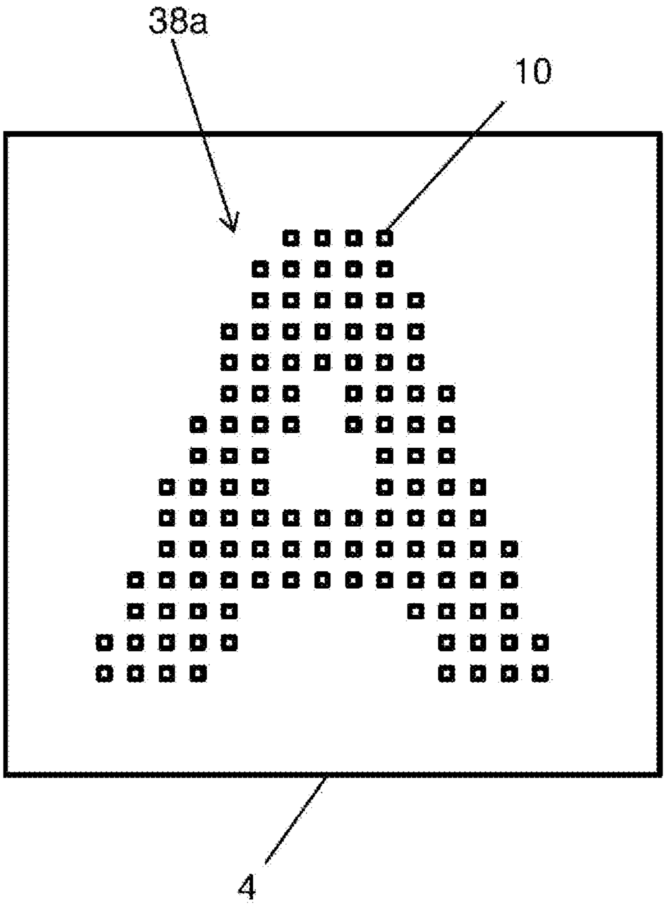


Figure 7

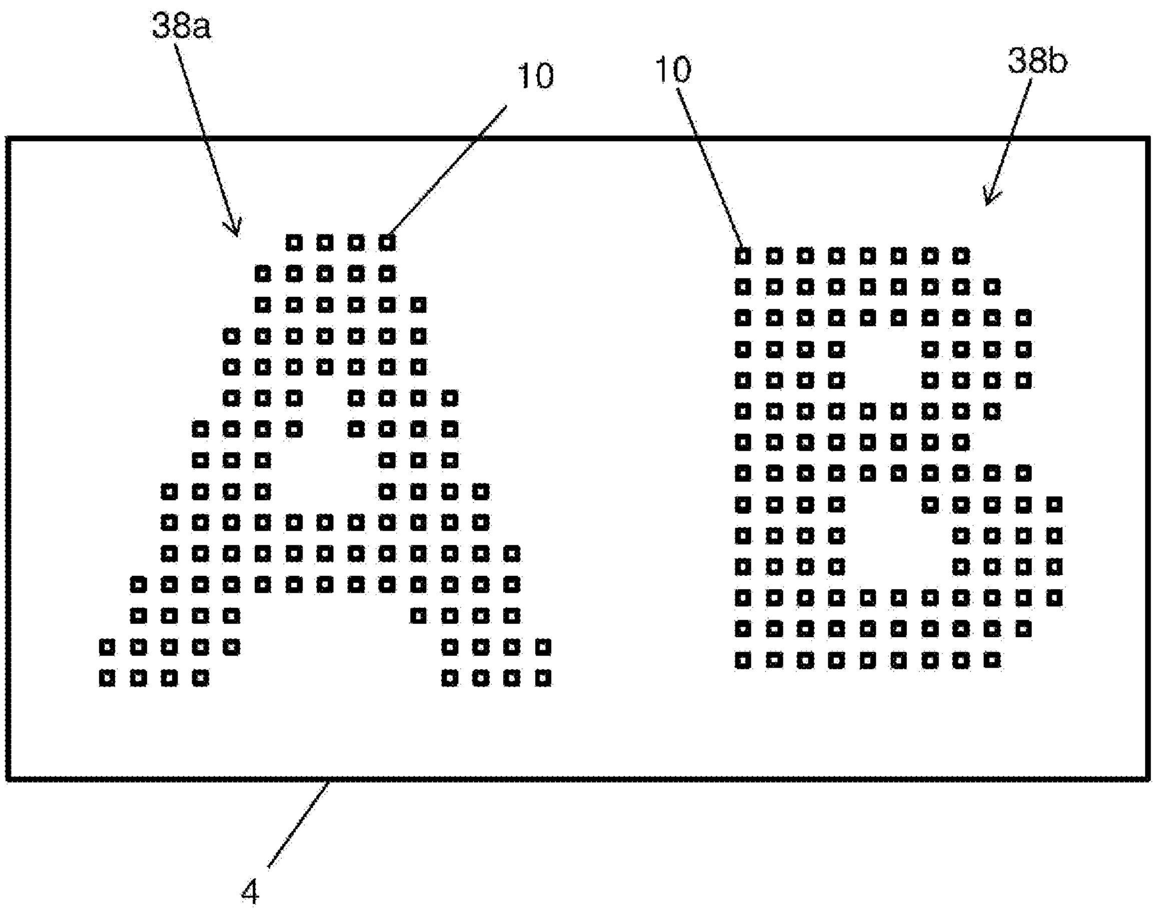
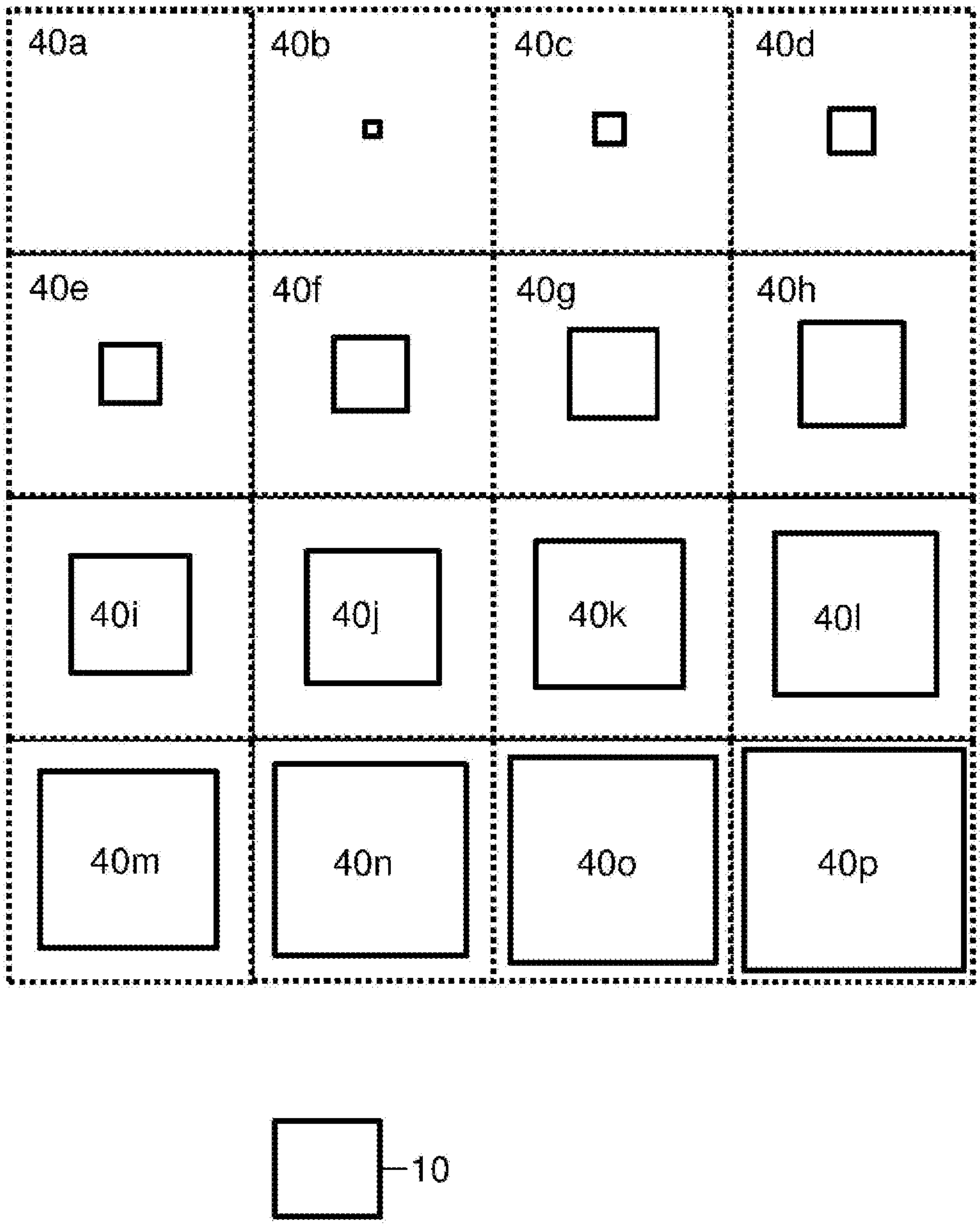


Figure 8



40a
40b
40c
40d
40e
40f
40g
40h
40i
40j
40k
40l
40m
40n
40o
40p
10

Figure 9

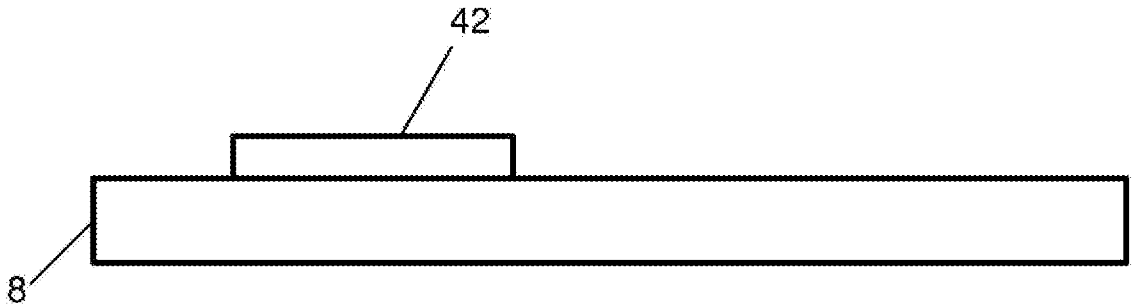


Figure 10

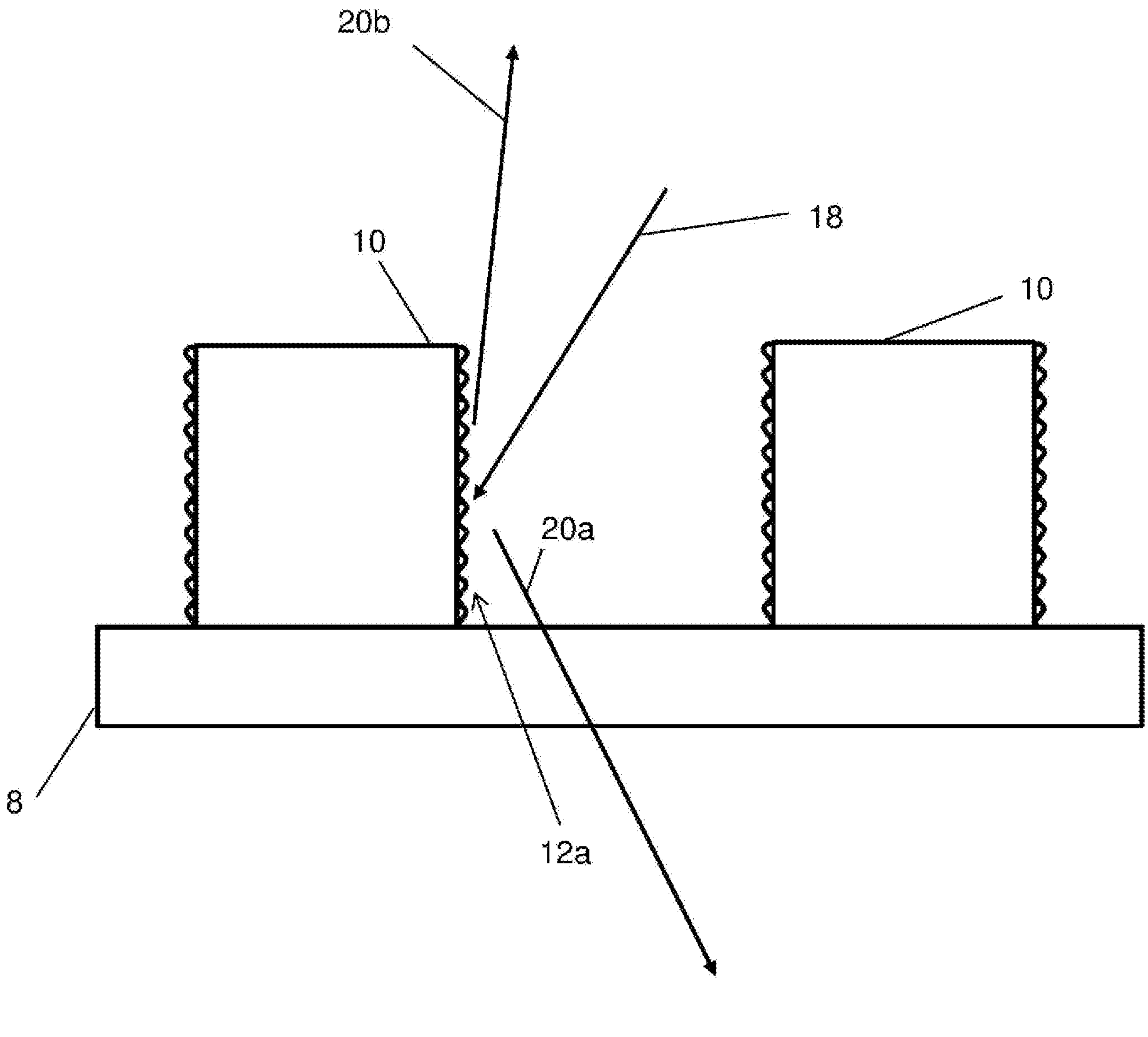


Figure 11

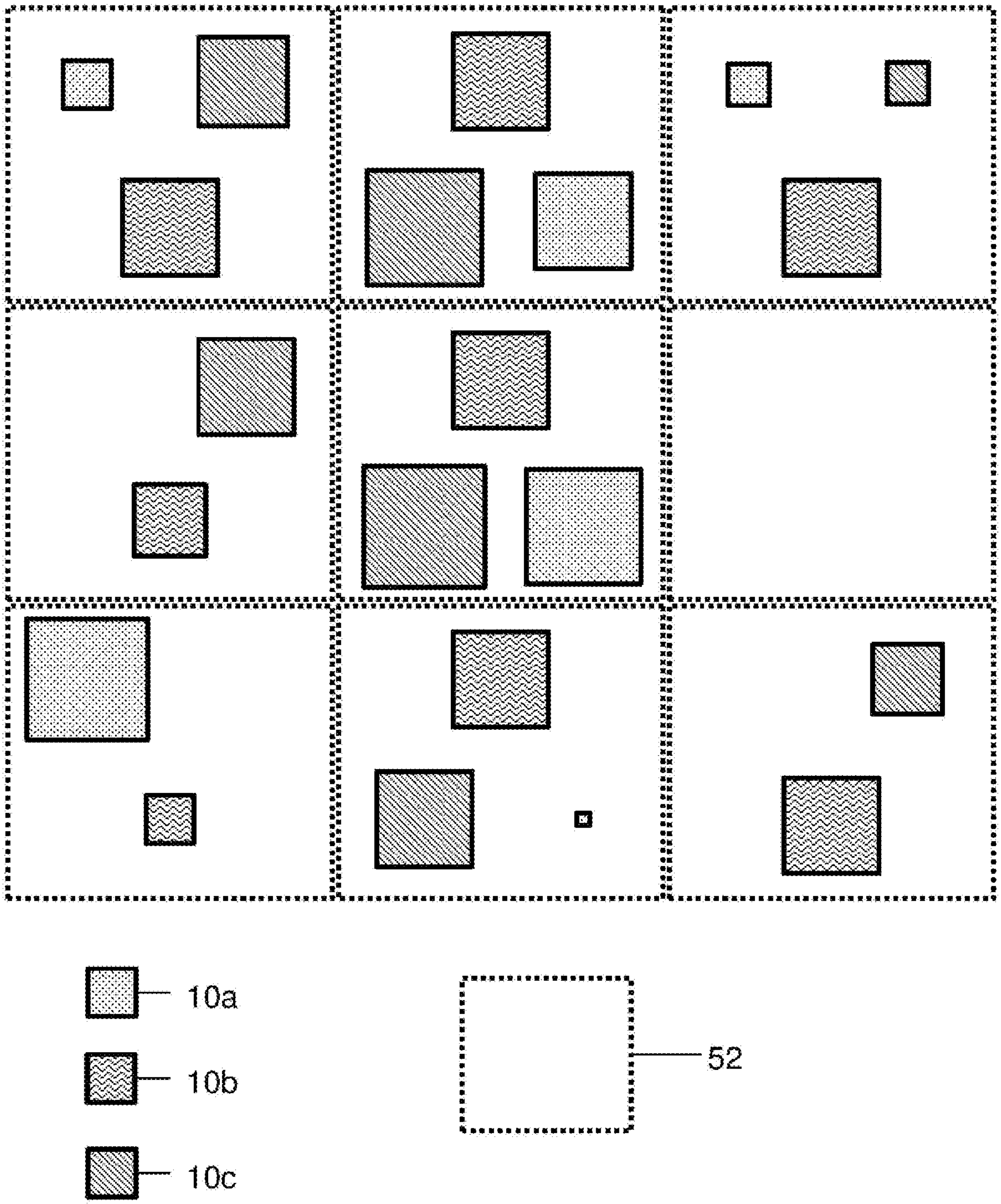


Figure 12

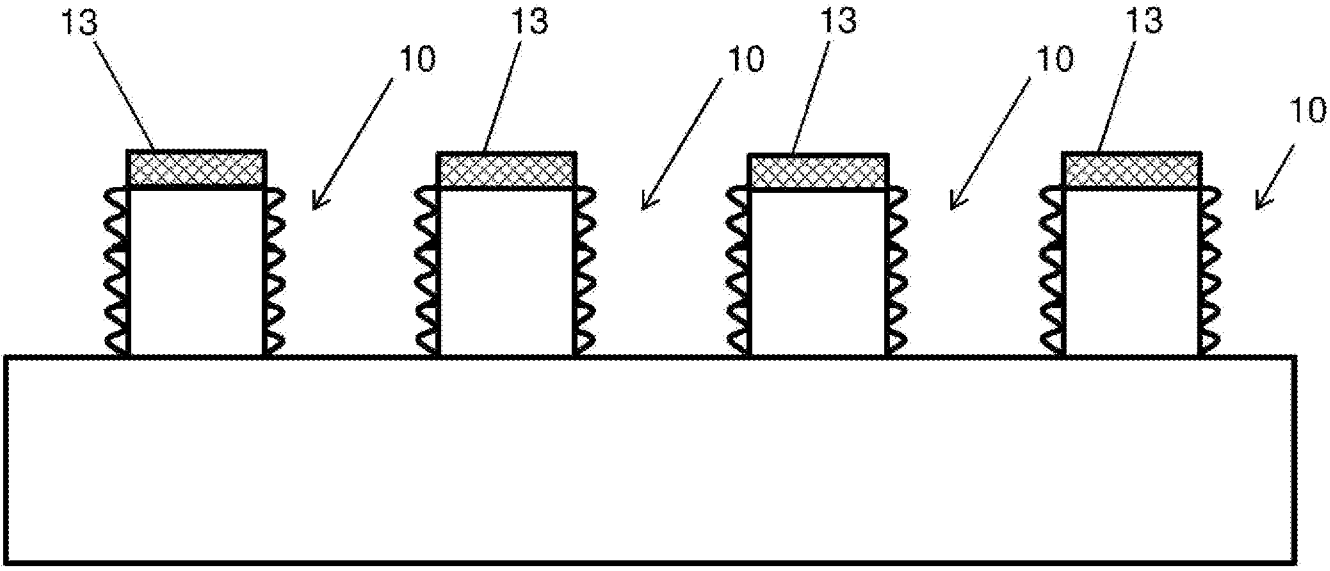


Figure 13

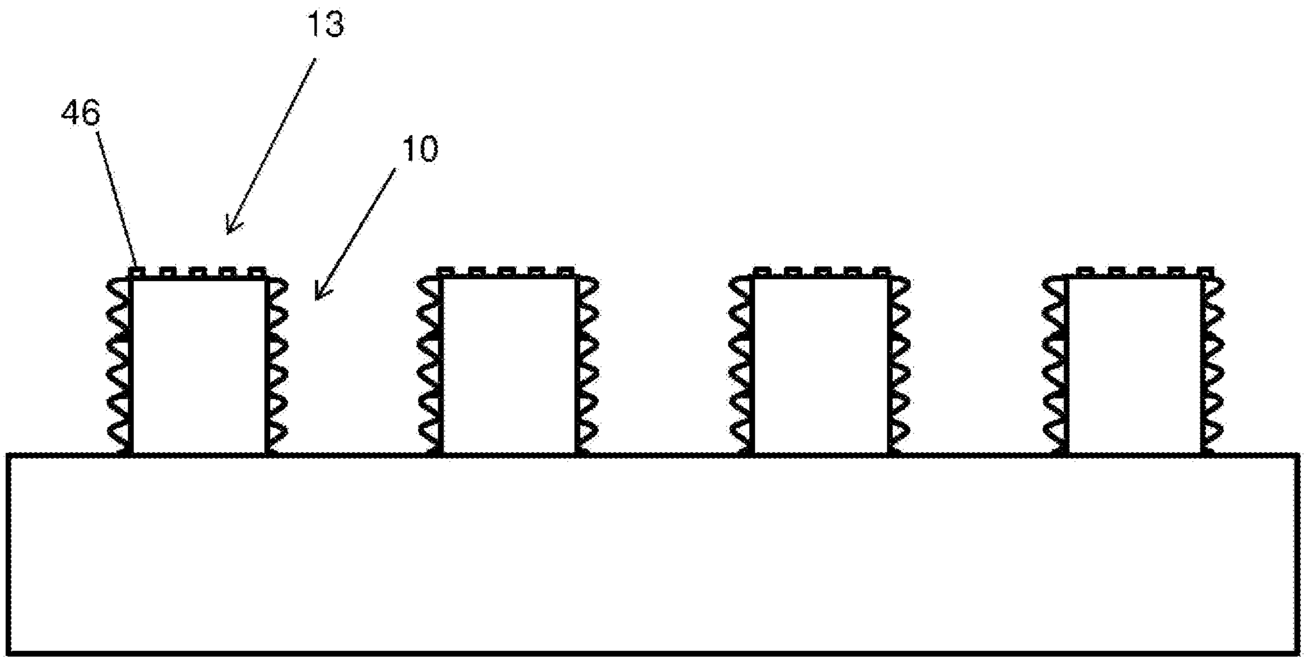


Figure 14

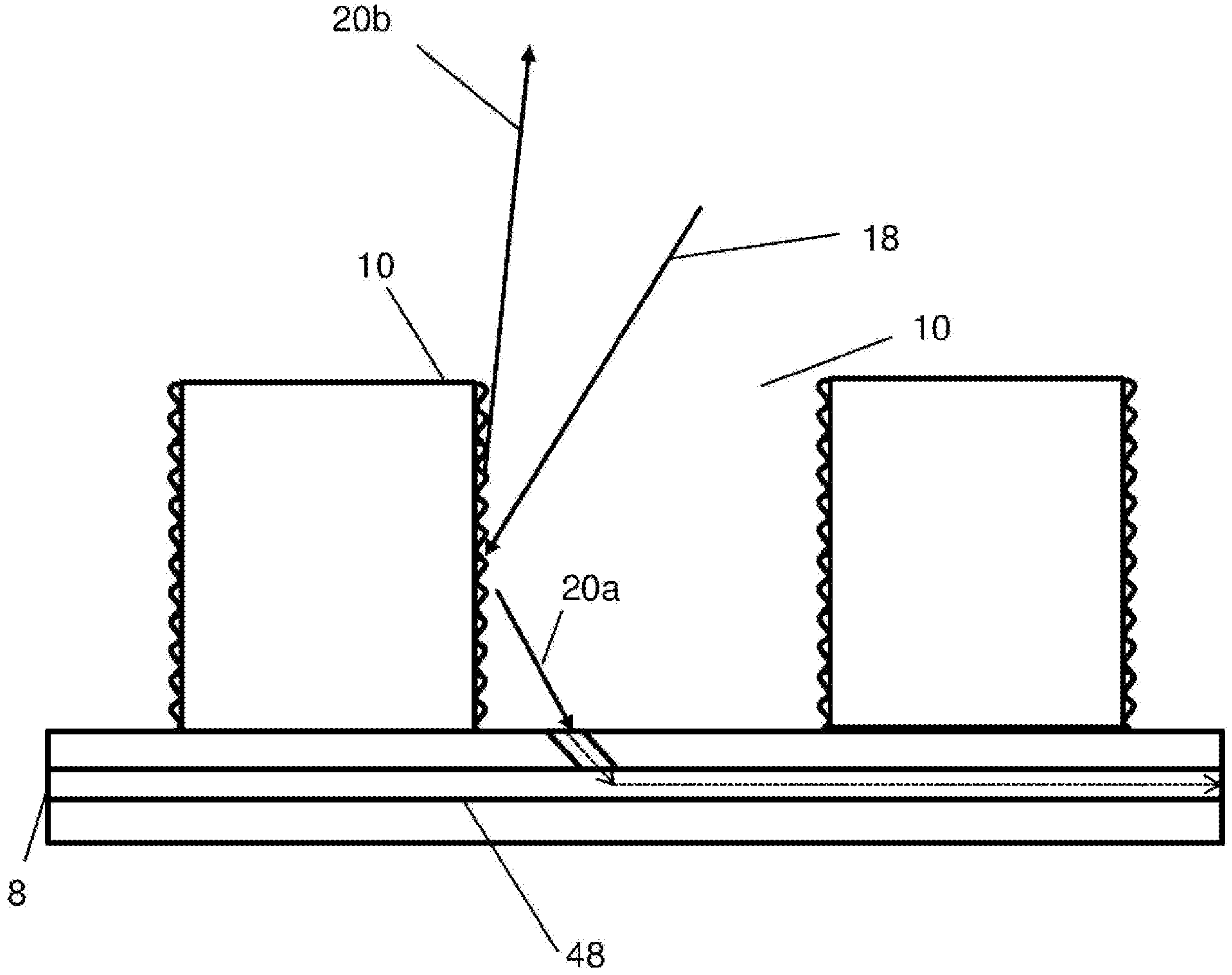


Figure 15

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2014/050041

A. CLASSIFICATION OF SUBJECT MATTER

B42D 25/328(2014.01)i, B42D 25/40(2014.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B42D 25/328; G03F 7/26; G02B 5/18; G03H ; G02B 27/44; B32B 33/00; B42D 15/00; B42D 25/40

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: pixel, optical, security, banknote, shim, emboss, etch, electroplate

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	W0 2012-0019226 Al (SECURENCY INTERNATIONAL PTY LTD.) 16 February 2012 See abstract, page 4, lines 1-3, page 6, lines 7-9, 19-20, page 12, lines 22-29, page 17, lines 12-14, claims 1,7,19,23,24,26,27, and figures 1,9.	1,4-14
A		2,3,15-20
A	US 2004-0175658 Al (MORALES et al.) 9 September 2004 See abstract, claims 1,32, and figure ID.	1-20
A	US 2013-0093172 Al (FUHSE et al.) 18 April 2013 See abstract, claims 1,19,20, and figure 12.	1-20
A	EP 1417517 Bl (COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANISATION) 22 December 2010 See abstract, claims 1,11, and figure 1.	1-20
A	WO 2004-0025378 A2 (ILLINOIS TOOL WORKS, INC.) 25 March 2004 See abstract, claims 1,9, and figure 2.	1-20

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22 August 2014 (22.08.2014)	**01 September 2014 (01.09.2014)**

Name and mailing address of the ISA/KR
International Application Division
Korean Intellectual Property Office
189 Cheongsa-ro, Seo-gu, Daejeon Metropolitan City, 302-701, Republic of Korea
Facsimile No. +82-42-472-7140

Authorized officer
KΓM, Jin Ho
Telephone No. +82-42-481-8699

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2012-019226 Al	16/02/2012	AU 2011-288969 Al	07/03/2013
		CN 103080816 A	01/05/2013
		DE 112011102365 T5	25/04/2013
		FR 2963834 Al	17/02/2012
		GB 201302246 DO	27/03/2013
		GB 2495680 A	17/04/2013
		MX 2013001569 A	21/03/2013
		US 2013-0258477 Al	03/10/2013
US 2004-0175658 Al	09/09/2004	US 2003-0215664 Al	20/11/2003
		US 2004-0173871 Al	09/09/2004
		US 6749997 B2	15/06/2004
		US 7008737 B2	07/03/2006
US 2013-0093172 Al	18/04/2013	AU 2010-327031 Al	21/06/2012
		CA 2780934 Al	09/06/2011
		CN 102905909 A	30/01/2013
		DE 102009056934 Al	09/06/2011
		EP 2507069 A2	10/10/2012
		RU 2012127687 A	20/01/2014
		WO 2011-066990 A2	09/06/2011
		WO 2011-066990 A3	28/07/2011
EP 1417517 Bl	22/12/2010	AU 2002-252818 B2	25/10/2007
		DE 60238686 Dl	03/02/2011
		EP 1417517 Al	12/05/2004
		EP 1417517 A4	04/06/2008
		US 2005-0052745 Al	10/03/2005
		US 7182476 B2	27/02/2007
		US 7281810 B2	16/10/2007
		WO 02-091041 Al	14/11/2002
WO 2004-025378 A2	25/03/2004	AU 2003-267108 Al	30/04/2004
		CN 1735843 A	15/02/2006
		EP 1576425 A2	21/09/2005
		EP 1576425 A3	28/09/2005
		JP 2005-538423 A	15/12/2005
		JP 2010-277100 A	09/12/2010
		KR 10-1005445 Bl	05/01/2011
		KR 20050039874 A	29/04/2005
		US 2004-101982 Al	27/05/2004
		US 6835948 B2	28/12/2004
		WO 2004-025378 A3	11/08/2005