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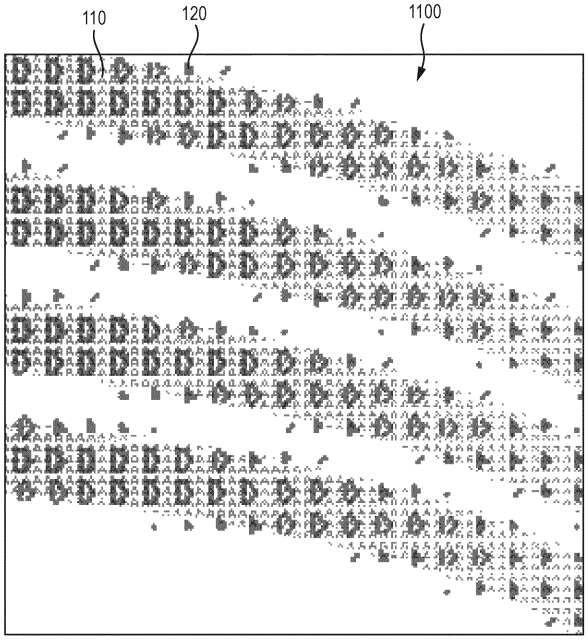
(54) SECURITY DOCUMENTS AND METHODS OF MANUFACTURE THEREOF

(57) The invention relates to a digitally printed security document. The security document comprises a security document substrate, a first digitally printed print working on a first surface of the substrate, the first print working comprising a first array of printed elements arranged according to a first grid of lattice points having a first pitch, the first array of printed elements defining a first screen of laterally distributed screen elements, each composed of multiple printed elements, and a second digitally printed print working on the first surface of the substrate, the second print working comprising a second array of printed elements arranged across a second grid of lattice points having a second pitch different from the first pitch, the second array of printed elements defining a second screen of laterally distributed screen elements, each composed of multiple printed elements, the second screen of laterally distributed screen elements being different than the first screen of laterally distributed screen elements. The screen elements of at least one of the first and second screens vary across the respective screen in one or more of the size, shape, spacing, number of printed elements, size of printed elements and spacing of printed elements of each screen element to provide areas of different colour or tone defining at least part of a multi-colour or multi-tonal image.

Fig. 4A



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Description

FIELD OF THE INVENTION

[0001] The present invention relates to digitally printed security documents, and methods of digitally printing security documents. The present invention is applicable to the field of security documents, including banknotes and, in particular, polymer banknotes.

BACKGROUND TO THE INVENTION

[0002] Because of the wide availability of digital printing systems, digitally printed security documents are generally viewed as nonviable as it is considered that counterfeits could be too widely produced and produced at levels that relatively convincingly replicate authentic documents. However, digital printing has certain advantages that it would be desirable to make use of in the security printing industry. In particular, digital printing does not rely on pre-produced printing plates and so would be particularly beneficial to short printing runs and for providing variable data, such as banknote serial numbers or passport identification data, that can differ between each printed security document. In order to address concerns regarding the security of digital printing techniques and thereby allow access to the benefits of digital printing in the security printing industry, it would be desirable to provide digital printing with improved security such that security documents can be produced using digital printing methods without compromising the high levels of security enjoyed by conventional security printing techniques.

SUMMARY OF THE INVENTION

[0003] According to a first aspect of the invention, a digitally printed security document comprises: a security document substrate; a first digitally printed print working on a first surface of the substrate, the first print working comprising a first array of printed elements arranged according to a first grid of lattice points having a first pitch, the first array of printed elements defining a first screen of laterally distributed screen elements, each composed of multiple printed elements; and a second digitally printed print working on the first surface of the substrate, the second print working comprising a second array of printed elements arranged across a second grid of lattice points having a second pitch different from the first pitch, the second array of printed elements defining a second screen of laterally distributed screen elements, each composed of multiple printed elements, the second screen of laterally distributed screen elements being different than the first screen of laterally distributed screen elements; wherein the screen elements of at least one of the first and second screens vary across the respective screen in one or more of the size, shape, spacing, number of printed elements, size of printed elements and spacing of printed elements of each screen element to provide areas of different colour or tone defining at least part of a multi-colour or multi-tonal image.

[0004] This provides a security document in which the printed elements, which are typically printed dots, are arranged to define a series of screen elements, with the printed elements having different characteristic spacings or pitch, i.e. defined by the grid of lattice points on which they may be arranged, said grid typically corresponding to the printing resolution with which the working was digitally printed. That is, the printing resolution, e.g. as determined by the spacing of the nozzles, the maximum print frequency of the nozzles and the feed control, influences the smallest possible pitch of the elements being printed by a print head, and by using different print heads, different smallest pitches may be provided for the two workings. The present arrangement clearly exhibits that different digital print processes were used to print the two screens and provides an authentication means, i.e. a characteristic which a viewer can look for to confirm the authenticity of a document. In contrast, if such a screen arrangement were printed on a conventional digital printer, in which all print heads have the same resolution, the two different workings would typically exhibit the same characteristic spacing of printed elements. Furthermore, the fact that the workings define two screens enhances the ability of a viewer to identify differences in the pitch of the grid of the working, i.e. since the viewer can inspect and compare relatively small individual screen elements, rather than having to compare large continuous regions of print.

[0005] By "screen", it is meant an array of laterally distributed elements whose characteristics may be spatially modulated across the layer so as to provide regions of visual contrast in an image. The arrays may be one-dimensional, e.g. an array of spaced lines, or two dimensional, e.g. an array of shapes or symbols. Each screen is formed by a respective digitally printed print working, i.e. a single digital print layer applied over the substrate. The printed elements, e.g. dots, of the digital print working are arranged according to respective lattices, which may be produced by digital print heads of different print resolutions. For example, if the first digital print working was printed by a digital print head operating at 600 DPI in both directions, there would be 600 possible print positions, i.e. lattice points, along every inch in the cross-feed direction and 600 possible print positions, i.e. lattice points, along every inch in the feed direction. However, as will be appreciated, not every possible print position will be occupied by printed element. The positions that do receive printed elements will be determined based on the design of the screen elements and the image being built up. However, the resolution of the print working will still be determinable based on the spacing of a number of elements across the working. These arrangements of printed elements will define the laterally distributed screen elements and each screen element will comprise a number of printed elements. Each screen element will typically include a number of adjacent printed elements,

i.e. arranged on adjacent lattice points of the grid of lattice points, but could also include printed elements spaced from one another or without neighbouring printed elements if this is required by the particular the screen element being used. For example in a square two-dimensional grid, as typically printed by a digital print head, each printed element will have eight neighbouring printed elements, and a series of neighbouring printed elements may build up the majority of each screen element. Examples of screen elements that may involve some internal spacing of printed elements would include the letter 'i' or any accented character. It should be noted that adjacent printed elements may or may not touch one another, depending on the size of the printed element (i.e. dot size) and the spacing of printed elements (i.e. the print resolution), but it is preferred that at least some of the adjacent printed elements do touch one another to present a more contiguous appearance to the screen elements.

[0006] The screens together define at least part of an image on the security document, such as a portrait, building, landmark, flag, etc., and the variation of the screen elements will produce the tone or colour variation of this image.

[0007] As mentioned above, the screen elements of at least one of the first and second screens vary, preferably gradually, across the respective screen in one or more of the size, shape, spacing, number of printed elements, size of printed elements and spacing of printed elements of each screen element to provide areas of different colour or tone. The term "size" will be understood to include the lateral dimensions of the screen element, as well as the weight or line width of the element. For example, a screen element having the shape of a letter 'A' may vary in its size by varying the dimensions of the letter, i.e. the font size, or by varying the weight of the lines making up the letter, i.e. varying the boldness of the letter. The term "spacing" will be understood to mean the centre to centre distance between adjacent screen elements. The number of printed elements, e.g. the number of dots, forming each screen element can also be varied and will typically depend on the desired size and shape of the screen element; however, it may also be possible to vary the number of printed elements without changing the size or shape, e.g. by reducing the density of printed elements within each screen element. Some digital print heads are also able to print different sized print elements, e.g. different sized dots, and so the screen elements may also vary in the size of printed elements to achieve the desired variation in colour and/or tone. Finally, the spacing of printed elements may vary by leaving certain lattice points empty or, using an example of a square grid, by printing only diagonally neighbouring dots, which will have a larger spacing distance than horizontally or vertically neighbouring dots. Some screen elements may include a mixture of printed element sizes (i.e. dot sizes) and/or spacings of printed elements, in which case the average printed element size and/or spacing within each screen element may vary across the screen.

[0008] The variation of the screen elements is used to provide multiple tones or colours of a multi-tonal or multi-coloured image. In particular, the variation of the screen elements may change the density of the working, i.e. the proportion of the substrate covered and uncovered by the working, across the substrate. Multiple tones may be produced, for example, where both workings are printed in materials with the same perceived colour or in regions where only one of the workings is disposed. Multiple colours may be produced, for example, where the workings are printed in materials with different perceived colours, by varying the relative proportions of these colours in an overlap region. It will be appreciated that the document may use the workings to provide imagery with multi-tonal and multi-coloured regions, as required.

[0009] While the first and second screens could include screen elements of the same, shape, size and spacing, it is preferred that the first and second screens of laterally distributed print element differ in the shape, size and/or spacing of the screen elements of the respective screens. For example, preferably at least one of the screen elements of the first or second screen has a shape, size or spacing to adjacent screen element(s) not found in the other screen. More typically, the screened workings will overlap one another, and one or more screen elements of one screen will differ in shape, size and/or spacing from the screen elements that they overlap of the other screen. In some embodiments, each screen element of the first screen will have a different shape, size or spacing from each screen element of the second screen, although this is not essential. For example, the first screen may be entirely made up of screen elements having the shape of the letter 'A' and the second screen entirely made up of screen elements having the shape of the letter 'B'.

[0010] Another way that the screen elements can vary from one another is by their makeup of printed elements. In some embodiments, the screen elements of the first screen differ from the screen elements of the second screen in the number of printed elements, the size of printed elements and/or the spacing of printed elements making up each screen element. As mentioned above, varying the number of dots making up each screen element can be achieved by varying the size of the screen element and/or varying the density of printed elements within the screen element. The size of the printed elements can also be varied, e.g. by using digital print heads to form the different screens that print with different dot sizes. The spacing of the printed elements will also typically be different because of the different grids of lattice points on which the printed elements of the two different workings can be arranged, and further spacing variation can be introduced by controlling which of the lattice points printed elements are provided on.

[0011] Typically, a plurality of the screen elements of the first screen have substantially the same shape, and/or wherein a plurality of the screen elements of the second screen have substantially the same shape,

wherein preferably said shape of the screen elements of the second screen is different from said shape of the screen elements of the first screen. Shape here means shape independent of size, so two screen elements defining the same letter 'A' but in different sizes will be considered to have the same shape. While each screen element could be a different shape, typically there will be repetition in the shape of the screen elements, although size and/or spacing could be varied to change the image tone or colour at any point. For example, a screen could be formed entirely of the letter 'A'. Alternatively, one screen could be formed by screen elements that vary in shape, e.g. having the shape of either '£' or '5', which would nevertheless repeat across the screen. The other screen may then have different shape screen elements, e.g. the letters 'U' and 'K', repeated across the screen.

[0012] While the screen elements may have any form, as will be clear from the above, it is particularly preferred that the screen elements carry information. That is, preferably, the screen elements of the first and/or second screen have the shape of one or more indicia carrying information, wherein preferably the screen elements define alphanumeric characters, symbols, logos and/or icons. That is, preferably the screen elements carry information by virtue of their shape. This is not essential, however, and the screen elements could be, for example, lines. Preferably the screen elements having the shape of indicia carrying information define different sets or arrangements of alphanumeric characters, symbols, logos or icons, preferably repeating sets or arrangements. An example of this would be screen elements defining the serial number of a banknote, i.e. each screen element defining a different digit, which serial number may repeat across the working to form a repeating set. Other repeating sets or arrangements may be used, such as the repeating of '£' and '5' which form a set reading "£5" that repeats across the document. Preferably, the different screens have screen elements or sets of screen elements carrying different information. For example, one screen may include a serial number and another screen may include the issuing bank. The use of indicia carrying information provides another mechanism of authentication, allowing a user to closely inspect the document not only for the different characteristics pitches of the printed elements forming the screen, but also to confirm that the expected information is defined by the screen elements.

[0013] Preferably, the screen elements of at least one of the first and second screens have the shape of one or more indicia that vary in size (typically also meaning a variation in size of printed elements and/or spacing of printed elements in each screen element) and/or spacing across the screen to provide areas of different tone or colour. That is, typically, the shape of the screen element will be dictated by the information that must be carried by the screen. Therefore, it is preferred that the screen elements vary in size and/or spacing to produce the tone or colour variations required for the image being depicted by the workings.

[0014] As mentioned above the screen elements can have the form of any indicia carrying information, but it is preferred that the screen elements of the first and/or second screen have the shape of one or more indicia carrying information (or sets or arrangements of indicia) relating to the digitally printed security document, such as serial number, denomination, currency, issue, bank and/or country information.

[0015] Preferably, at least some of the laterally distributed screen elements of the first second screen are spaced from the neighbouring screen elements of the first screen and/or wherein at least some of the laterally distributed screen elements of the second screen are spaced from the neighbouring screen elements of the second screen. That is, it is preferred that there is a gap in the print working, i.e. unoccupied lattice points, between one screen element and the next, at least in part of the screen. This facilitates recognition of the screen elements and comparison between screens. However, it will be appreciated that some parts of the screen, e.g. corresponding to dark tones of the image, may requires a density of printed elements that necessitates a very close centre-to-centre spacing of the screen elements such that there may be no gap in the print working between adjacent screen elements.

[0016] Typically, a plurality, preferably each, screen element in the first and/or second screen includes a plurality of printed elements having a spacing corresponding to the respective first and/or second pitch of the first and/or second grid of lattice points. That is, the grid of lattice points will typically correspond to the maximum print resolution of the digital print head, and it is preferred that many or all of the screen elements exhibit this maximum resolution to facilitate comparison of the grid pitches when authenticating the security document.

[0017] While it is possible that variations in tone or colour of the image may be provided by only one of the screens varying, e.g. with the other screen being uniform across the image, it is preferred that the screen elements of both of the first and second screens vary across the respective screen in one or more of the size shape, spacing, number of printed elements, size of printed elements and spacing of printed elements of each screen element to provide areas of different colour or tone defining at least part of a multi-colour or multi-tonal image. In many cases, both screens will vary as required by the multi-tonal or multi-colour image. For example, one screen may be relatively coarse, e.g. large and widely spaced screen elements, while the other screen is relatively fine, e.g. small, closely spaced screen elements, in which case the coarse screen may provide coarse image portions, e.g. backgrounds and shading, while the fine screen may provide detail portions of the image, e.g. details in a portrait., with the overall colour and tone nonetheless being contributed to by both screens.

[0018] As will be clear from the above, it is preferred that the first screen of laterally distributed screen elements is provided across a first region and the second

screen of laterally distributed screen elements is provided across a second region at least partially overlapping the first region. This provides a number of benefits, including facilitating authentication by comparing the screen elements of the two screens, also increasing the image fidelity by allowing for control of image detail using either or both of the two workings and finally making counterfeiting more difficult by making it more difficult to separate the two workings when trying to deconstruct and copy the printed image. It should be noted, however, that non-overlapping workings may be used, if desired. Where the workings do overlap, preferably one or more of the screen elements of the first screen differ from one or more, preferably each, of the screen elements of the second screen in size, shape and/or spacing of the screen elements where the first and second regions overlap. Indeed, one or more of the screen elements of the first screen overlap one or more of the screen elements of the second screen, e.g. the printed elements overlap, said overlapping screen elements preferably differ in size, shape and/or spacing. That is, the screen elements in the overlapping workings will often overlap, and often a large screen element may overlap several small screen elements. In which case, preferably the overlapping screen elements differ from one another so that the differences in the screen can be more readily identified.

[0019] Preferably, the screen elements of at least one of the first and second screens vary, preferably gradually, in one or more of the size, shape, spacing, number of printed elements, size of printed elements and spacing of printed elements across the overlap of the first and second regions to provide areas of different colour or tone defining at least part of a multi-colour or multi-tonal image in the overlap of the first and second regions. That is, as has been explained above, the region of the overlap uses variation in one or both screens to control the tone or colour of an image that is defined by the combination of the two screens. Providing this portion of the image as multi-coloured or multi-tonal ensures that it is difficult to counterfeit both the image content and the screen content, enhancing security. In such embodiments, preferably the screen elements of the first and second screens vary differently across the overlap of the first and second regions to provide areas of different colour or tone defining at least part of a multi-colour or multi-tonal image in the overlap of the first and second regions. Different variation of the screens introduces additional complexity that makes counterfeiting even more difficult and also provides for further control of the tone and/or colour of the image defined in the region of the overlap.

[0020] While the two print workings could be printed using the same material, e.g. the same ink, preferably the first digitally printed print working is printed in a first material, preferably a first ink, and the second digitally printed print working is printed in a second material, preferably a second ink, different from the first material. The use of different materials allows the workings to have different properties, such as different colours, or facilitates different printing heads with different dot sizes or resolutions, e.g. by having material with different viscosities or pigment sizes suited to particular print heads or nozzle sizes, etc. It will be appreciated that particularly preferred embodiments provide that the first and second materials have different optical characteristics. In many examples of this, the first material has a first colour and the second material has a second colour different from the first colour, i.e. under standard viewing conditions. Different coloured workings helps a viewer to distinguish the two workings and so facilitates authentication by checking that each working has its assigned print element pitch. Furthermore, the use of different coloured workings, where they overlap, allows for multi-coloured imagery to be generated by varying the workings relative to one another. That is, the screen elements of at least one of the first and second screens may vary across the respective screen in one or more of the size, shape, spacing, number of printed elements, size of printed elements and spacing of printed elements of each screen element to provide areas of different colour defining at least part of a multi-colour image in the overlap of the first and second regions.

[0021] While different colours is one example of materials with different optical characteristics, other optical characteristics may be varied between the materials. For example, the first and/or second inks may be metallic inks, colour shifting inks, metameric inks, luminescent inks, fluorescent inks, phosphorescent inks, infrared-absorbing inks, thermochromic inks and/or photochromic inks. Particularly preferably the two inks represent different selections from this list as this will provide distinctly different optical characteristics to the two workings; however, the inks could also be of the same type, e.g. gold and silver metallic inks.

[0022] Whether or not the workings are in different colours, preferably at least one of the first and second workings is printed in material having a colour that is not one of CMYK, and preferably at least one of the first and second workings is printed in material having a colour that lies outside of the CMYK colour gamut. CMYK colours are considered to be those used in conventional CMYK printing, as will be described in more detail below. Printing in non-standard colours, ensures that the appearance of the resulting printed security document is more difficult to accurately replicate with a conventional CMYK printer. In particular, a non-CMYK colour will typically require a combination of CMYK inks to replicate, if the colour can be replicated at all, i.e. if the colour lies inside the CMYK colour gamut. If a screen with a non-CMYK colour is replicated by a CMYK printer, a viewer will be able to see this by inspecting the screen elements and seeing that each screen element within one screen is in fact formed by two workings of different colours. The discrete screens therefore provide a viewer with a powerful mechanism for authenticating the documents by inspecting the ink colours used.

[0023] Specific information concerning CMYK values

may be found in the ISO12647 standard. In particular, the ISO12647-7 standard specifically deals with "Proofing processes working directly from digital data". As set out in this standard, a colour will be considered to be one of CMYK if the Euclidean distance ΔE^*_{ab} (often referred to as "Delta E") between the colour used and any one of CMYK in CIELAB colour space (i.e. the CIE 1976 L*a*b* colour space) is 5 or less. The value of ΔE^*_{ab} is measured using the formula

$$\Delta E^*_{ab} = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$$

[0024] Where ΔL^*, Δa^* and Δb^* are the distance between the two colours along the L*, a* and b* axes respectively (see "Digital Color Imaging Handbook" (1.7.2 ed.) by G. Sharma (2003), CRC Press, ISBN 0-8493-0900-X, pages 30 to 32). The colour difference ΔE^*_{ab} can be measured using any commercial spectrophotometer, such as those available from Hunterlab of Reston, Virginia, USA. With the CMYK colours being defined by ΔE^*_{ab}, the CMYK colour gamut will be considered as the range of colours producible by all possible combinations of CMYK up to $\Delta E^*_{ab} = 5$.

[0025] It is particularly preferred that the first and/or second array of printed elements positively define the corresponding first and/or second screens, i.e. positively define the screen elements. By "positively defined" it is meant that the presence of printed elements defines screen elements. As an alternative, one or both of the screens may be negatively defined, i.e. have negatively defined screen elements. In this alternative, the absence of printed elements defines the screen elements. In some examples, one or both screens may have both positive and negative regions, i.e. regions in which the screen elements are positively defined and regions in which the screen elements are negatively defined, which can maintain the clarity of the screen elements while increasing the range of colours that can be produced by the workings. That is, a combination may be used to negatively define screen elements in regions where a high ink coverage is required, e.g. dark tones or highly saturated colours, while the positive regions may provide regions of the image where relatively low ink coverage is required, e.g. light tones or low saturated colours. Typically, positively defined screen elements will be preferred to facilitate comparison of the screen elements and aid authentication.

[0026] In many embodiments, the first grid of lattice points is a two-dimensional grid of lattice points defined by a first unit cell, and the second grid of lattice points is a two-dimensional grid of lattice points defined by a second unit cell, wherein the first and second unit cells are different from one another. The grid of lattice points defines the possible printed element locations and since a digital print head will typically print at a constant print resolution, the grid will typically be defined by the repeating unit cell referred to above. While the unit cell defines possible printed element locations, not every location need be provided with a printed element and indeed it is by selectively providing the printed elements that the screen is built up. It should be noted that while such a unit cell is preferred, it is not essential that the grid of lattice points be regular. For example, the digital print head used to produce the security document may have irregular spacing of the nozzles which will lead to security documents with a similarly irregular array of lattice points.

[0027] Preferably, the first and second grids are each regular, square grids of lattice points, or rectangular grids of lattice points. These are the types of grids printed by the majority of digital print heads and a viewer may readily compare the two grids in order to confirm authenticity. Preferably, the first grid of lattice points has a pitch in each of two orthogonal directions and the second grid of lattice points has a pitch in each of two orthogonal directions, wherein optionally each pitch of the first grid of lattice points is different from both pitches of the second grid of lattice points. Preferably one of the first and second pitches of the grids of lattice points is a non-integer multiple of the other. This effect is harder to replicate without a custom digital printing press.

[0028] Digital print heads that print at different resolutions will typically print with different dot sizes and indeed this can be used as a further authentication feature, allowing a viewer to inspect the documents to confirm that the workings have dot sizes of the expected sizes. Preferably at least some of the printed elements of the first array of printed elements have a smallest lateral dimension smaller than, preferably 25% smaller than, more preferably 50% smaller than, a smallest lateral dimension of the printed elements of the second array of printed elements, and/or wherein at least some of the printed elements of the second array of printed elements have a smallest lateral dimension larger than, preferably 50% larger than, more preferably 100% larger than, a smallest lateral dimension of the printed elements of the second first of printed elements. In particular, a large difference in dot sizes may be more readily authenticated and is also more difficult to counterfeit with a conventional digital printer since, in particular, a print head that can print at the highest resolution required by the two workings may not be capable of printing larger dot sizes used in the lower resolution working.

[0029] The first working will preferably be higher resolution than the second working and so preferably the pitch of the first grid of lattice points corresponds to a print resolution of at least 600 DPI, preferably at least 900 DPI, more preferably at least 1200 DPI, in at least one direction. For this high-resolution working, preferably at least some of the printed elements of the first array of printed elements have a smallest lateral dimension of at most 200 micrometres, preferably at most 100 micrometres, more preferably at most 50 micrometres, most preferably at most 20 micrometres. The second working will also preferably be lower resolution than the first working and so preferably the pitch of the second grid of lattice

points corresponds to a print resolution of at most 600 DPI, preferably at most 360 DPI, further preferably at most 200 DPI, in at least one direction. For this low-resolution working, preferably at least some of the printed elements of the second array of printed elements have a smallest lateral dimension of at least 20 micrometres, preferably at least 50 micrometres, more preferably at least 100 micrometres most preferably at least 200 micrometres. It will be appreciated that the second working could be high resolution and the first working low resolution as an alternative to the above.

[0030] To ensure that the different resolutions of the print heads used to print the two workings is clearly visible, preferably the first print working comprises a printed element on each lattice point of the first grid of lattice points across at least a sub-region of the first region such that the first array of printed elements has the first pitch across said sub-region. Similarly, preferably the second print working comprises a printed element on each lattice point of the second grid of lattice points across at least a sub-region of the second region such that the second array of printed elements has the second pitch across the second sub-region. Particularly preferably, the first and/or second working comprises a printed element on each lattice point of the respective first grid of lattice points within a plurality of the screen elements, preferably within each screen element, in the respective screen. This provides the highest resolution in the screen elements to facilitate comparison of the resolutions of the print elements of the two screens.

[0031] The present invention is suitable for use in all types of security document, but preferably the security document is a polymer security document, i.e. the security document substrate comprises a polymer substrate. Polymer substrates are typically more difficult to digitally print, as most digital printers are designed to handle and print on paper. This can mean that phenomenon such as static of the polymer substrate, which impacts feed through a digital printer, also need to be overcome in order to attempt to counterfeit the present security document. Particularly preferably, the polymer substrate is transparent and the security document substrate further comprises one or more opacifying layers, typically white opacifying layers, applied over at least part of the transparent substrate. In such cases, the one or more opacifying layers may be omitted on one or both sides of the substrate to form window or half-windows in the security document, or could be provided across the whole security document. Typically, the first and second print workings will overlap the opacifying layers (and overlap one another over the opacifying layers), but one or both workings may also extend into any windows of the security document. Providing the workings over the opacifying layers facilitates comparison of the workings as, for example, they may be clearly seen against a plain background. However, having the workings extend into one or more windows or half-windows may present further difficulties for counterfeiters, who must be able to replicate this ability to print in both regions. Indeed, in some cases, it may be desirable for the workings to overlap in one more window or half-windows and/or to be provided only in the window or half-windows, as this may be the most difficult location for a counterfeiter to print and may present the print more clearly as an authentication feature to viewers, i.e. as they are accustomed to checking window features for security devices.

[0032] As mentioned above, the security document may take any form, but preferably the security document is a banknote, travellers cheque, certificate of authenticity, stamp, bond, tax disc, fiscal stamp, secure label, passport or voucher.

[0033] Typcially, a plurality of security documents, each formed according to the above principles, will be provided and indeed the present invention has a number of particularly preferred ways in which it may be implemented across a plurality of documents.

[0034] In preferable embodiments, the screen elements of at least one of the first and second screens of laterally distributed screen elements differ on each of the plurality of security documents. For example, at least one screen element on a first document may differ from the corresponding screen element (i.e. the one in the same position) on a second document. Preferably, the screen element will differ in shape, e.g. differ in the information content of the screen element, such as by having the shape of a different alphanumeric character, symbol, logo or icon. In other words, preferably, the screen elements of at least one of the first and second screens of laterally distributed screen elements differ in the information conveyed by the screen elements on each of the plurality of security documents. An advantage of digital printing is that the print content can be varied from document to document. In contrast, more conventional security document printing techniques, such as lithographic, flexographic and gravure printing techniques, rely on predefined print plates which print the same content on each security document. However, so that the security documents are recognisable, it will typically be desired for the overall image to appear substantially the same, e,g, to include the same portrait, design content and indication of denomination or value. In such cases, varying the screen elements provides one way of using the variability providable by digital printing without significantly altering the overall appearance of the security document. For example, a banknote may be formed in which the serial number is used as the screen elements and is used to define the image content of the banknote so that the image is the same on each banknote but the set of screen elements are unique to a particular note. Another example would be a passport provided with an owner's name defining the images on the pages. Varying the print content between security documents ensures that the security documents cannot be counterfeited by more conventional security printing techniques. Advantageously, the first and second screens of laterally distributed screen elements may not be registered to one another, such that

the relative position of first and second screens varies between the security documents. That is, because the workings are forming entirely separate screens, there is no requirement for the workings to be registered to one another. Again, this is another way of demonstrating that secure digital printing was used to form the workings. If, for example, a counterfeiter used a more conventional security document printing system, such as a flexographic, lithographic or gravure printer, to print a replica of the image, the fixed nature of the plates used in these techniques would manifest as completely registered print workings. This also facilitates manufacture of the authentic security documents.

[0035] Another aspect of the invention provides a method of digitally printing a security document, the method comprising: providing a security document substrate; digitally printing a first print working on a first surface of the substrate using a first print resolution such that a first array of printed elements is provided in accordance with the first print resolution, the first array of printed elements defining a first screen of laterally distributed screen elements, each composed of multiple printed elements; digitally printing a second print working on a first surface of the substrate using a second print resolution different from the first print resolution such that a second array of printed elements is provided in accordance with the second print resolution, the second array of printed elements defining a second screen of laterally distributed screen elements, each composed of multiple printed elements, the second screen of laterally distributed screen elements being different than the first screen of laterally distributed screen elements; wherein the screen elements of at least one of the first and second screens vary across the respective screen in one or more of the size, shape, spacing, number of printed elements, size of printed elements and spacing of printed elements of each screen element to provide areas of different colour or tone defining at least part of a multi-colour or multi-tonal image.

[0036] This corresponds to a method of printing the security document according to the first aspect of the invention and may also be used to print a plurality of security documents according to the second aspect. It will be appreciated that this method may be adapted to print the security documents having any of the advantageous features discussed above.

[0037] This method involves printing the two different workings with different print resolutions. As indicated above, the print resolution is typically determined by, for example, the spacing of nozzles on a digital print head, the dispensing frequency of the nozzles of the digital print head and/or the feed control. This will manifest as the different grids of lattice points on which the print elements are arranged in each print working. Conventional digital printers will typically feature digital print heads all having the same resolution and so will be unable to replicate the different grids of lattice points in each print working. By printing with different print resolutions, as is the case in the present invention, and specifically in such a way as to form the varying screen elements described above, it can be ensured that the security document may be inspected to confirm that it was printed by a secure digital printing technique.

[0038] The method will typically be executed by a digital printing press comprising first and second digital print heads that respectively print the first and second workings. The method may involve the generation of a set of printing instructions for operating the digital printing press. The printing instructions may include printing instructions at a first resolution (i.e. the resolution of the first digital print head) for controlling the first digital print head to print the first print working and printing instructions at a second resolution (i.e. the resolution of the second digital print head) different from the first resolution for controlling the second digital print head to print the second print working. The instructions may be generated based on a source image that defines the multi-tonal image to be printed. This source image may be designed with multiple layers corresponding to the different workings to be printed and preferably at resolutions corresponding to the print heads that will be used to print the respective layers. Preferably, digitally printing the first and/or second print working comprises inkjet printing the first and/or second print working. Inkjet printing heads are widely available and so this reduces the cost of manufacture; however, security is maintained by the screen printing arrangement described above.

[0039] Again, the first and second print workings need not be printed in register with one another and the screens may be printed entirely separately and out of register. This contrasts with, for example, plate printing techniques in which any screens formed on the same plate will inevitably be in register with one another.

[0040] The method may also comprise printing the first and second print workings in different print passes. This could, for example, involve the printing of a first working defining a first screen, which is the same on each document, at a first stage in the manufacture process, followed by the later printing of a second working defining the second screen, which may include individualised screen elements, e.g. screen elements corresponding to the serial number of a banknote or name on a passport.

[0041] To individualise a security document, the method may further comprise receiving identifying information specific to the security document being printed, preferably unique to the security document printed, and printing at least one of the first and second workings such that the first and/or second screens comprises screen elements having the shape of one or more indicia corresponding to the identifying information. Information specific to the security document may include, for example date of issue or date of printing, which may be the same for a number of printed documents, while information unique to the security document may include, for example, serial numbers. The screen elements may correspond to identifying information in a number of ways.

Preferably, the identifying information is fully depicted, e.g. by a set or arrangement of screen elements having the form of alphanumeric characters. However, other ways of using the identifying information may be used, such as using the first letter of a surname as the design of the screen elements of one screen on a passport.

BRIEF DESCRIPTION OF THE DRAWINGS

[0042] The invention will now be described with reference to the accompanying drawings, of which:

Figure 1 shows, schematically, a digital printing press suitable for printing security documents according to the invention;
Figure 2 shows, schematically, two different digital print heads suitable for printing security documents according to the invention
Figures 3A and 3B shows, schematically, a security document according to the invention in plan and cross-section views respectively;
Figures 4A and 4B show a portion of the image printed on the security document of Figures 3A and 3B at two different levels of magnification;
Figures 5A and 5B show a portion of an alternative image that may be printed on a security document according to the invention;
Figures 6A and 6B show a portion of one screen that may be printed on a security document at two different levels of magnification;
Figure 7 shows another alternative image that may be printed on a security document according to the invention;
Figures 8A, 8B and 8C show three different regions of the image shown in
Figure 7; and
Figure 9 is a flow diagram illustrating a method of customising the screen of a security document according to the invention.

DETAILED DESCRIPTION

[0043] A digital print press suitable for printing security documents according to the invention will now be described with reference to Figure 1.

[0044] Figure 1 shows a digital printing press. The digital printing press comprises an array of print bar holders 10a to 10j. Each of the print bar holders is able to receive and support a respective digital print bar over a substrate 100. In Figure 1, only the first and second print bar holders 10a and 10b are illustrated as holding a respective print bar 11a and 11b. These print bars are used to print the screens according to the invention, but in practice, more print bars may be provided in respective ones of the print bar holders 10a to 10j, up to the maximum of 10 permitted on the illustrated machine, in order to print different features of a security document.

[0045] The digital print press 1 comprises a transport system 20. The transport system 20 feeds a web of substrate 100 from a pre-print spool 21 to a post-print spool 22. Between the pre-print and post-print spools 21 and 22, the web of substrate 100 is fed sequentially past each print bar supported by the respective print bar holders 10a to 10j in such a way as to allow the digital print heads of the digital print bars to print onto the first surface (upper surface) of the web of substrate material 100. The web of substrate material 100 is fed between the pre-print and post-print spools 21 and 22 by a plurality of rollers 23, which act to guide and support the substrate web 100 as it passes through the digital print press 1.

[0046] The first print bar 11a comprises a first digital print head 12a located at the bottom of the print bar 11a. Similarly, the second print bar 11b comprises a second digital print head 12b located at the bottom of the print bar 11b. The digital print heads 12a and 12b face down so as to be able to print onto the upper facing surface of the substrate web 100 as it is conveyed through the digital print press 1, sequentially beneath each of the digital print bars. The digital print press also includes a controller 30 adapted to control the various print bars installed in the print bar holders 10a to 10j. In some modifications, the controller may also be responsible for generating the printing instructions for operating the digital print heads, or may be electronically transmitted preprepared printing instructions. The controller may also be linked to a database and may retrieve identifying information relating to the security document being printed, such as serial number of a banknote, and may generate the printing instructions using the identifying information, e.g. by forming the screen elements with shapes corresponding to the digits of the serial numbers.

[0047] The system may be fitted with conventional print bars, some examples of which will now be given. One print bar that may be included in the digital print press is the Dimatrix Samba G3L manufactured by Fujifilm Dimatrix, which prints with a resolution of 1200 DPI and drop sizes of 2.4 to 13 picolitres, and may be configured to print in red using aqueous or UV inks and may print fine line patterns or microtext onto the security document substrate. Another example is the KM1800i, manufactured by Konica Minolta, which prints at 600 DPI and with drop sizes of 3.5 to 18 picolitres and may print in green or orange using aqueous, solvent, UV and speciality inks, and is suitable for printing more general design elements of the printed security document, such as portraits or backgrounds. Another example is the Saffire QS256, manufactured by Fujifilm Dimatrix, which prints at 100 DPI with drop sizes of 10, 30 and 80 picolitres, and may use UV, aqueous, thermochromic, MICR and conductive inks, for example. A further print bar that may be used is the KM1024, manufactured by Konica Minolta, which prints at 360 DPI with drop sizes of 6, 14 and 42 picolitres, and may use aqueous, solvent, UV and speciality inks. As will be described below, the digital print press is configured such that the different print heads print at distinctively different resolutions, so in practice, different print

bars will typically be installed into the digital print press.

[0048] Figure 2 shows one specific set-up of the digital print press of Figure 1 for printing a security document according to the invention. In this example, the first digital print head 12a is configured to print with a resolution of 1200 DPI, drop sizes from 2.4 to 13 pl, and in the colour violet. The nozzle size of this print head may be 5 microns. This high-resolution print head is configured to print a first working 110 defining a series of screen elements 111 onto the surface of the substrate 100. The form of this working will be described below. The second digital print head 12b is configured to print with a resolution of 360 DPI, drop sizes of 14 or 42 pl and in the colour orange. The nozzle size of this print head may be 40 microns. This may print a second working 120 composed of screen elements 121. It should be noted that the nozzle pitch of the above print heads will be equal to the resolutions with which they are configured to print. 1200 and 360 DPI is an example of print heads having nozzle pitches that share a non-integer multiple relationship. The resulting printed resolution will likewise share a non-integer multiple relationship. In this example, each digital print head extends the full width of the transport path so as to be able to print on the whole document surface.

[0049] Figures 3A and 3B show, schematically, a security document according to the invention that may be printed using the digital print press described above. In this example, the security document is a banknote 1000. For simplicity, the banknote 1000 is shown as comprising a security document substrate 100 composed of a transparent polymer supporting substrate 101 coated on opposing surfaces thereof with opacifying coating layers 102a, 102b defining a stripe window 1010, but the security document substrate may comprise further layers, such as additional opacifying layers, antistatic coatings, primer coatings, and the like. On the security document substrate is printed a printed multi-colour image 1100 on one surface, printed over the opacifying coating 101a. In practice, security documents will include a number of other features, including additional printed elements, e.g. indicating currency, denomination, etc., and security features, such as foils and optically variable devices including diffractive devices, such as holograms, and lens-based security devices, such as lenticular or moire magnification devices, arranged for example in the window 1010.

[0050] The supporting polymer substrate 101 is preferably a transparent substrate, such a bi-axially oriented polypropylene (BOPP). Each opacifying layer 102a, 102b comprises a translucent, semi-opaque material which is preferably polymeric and non-fibrous, e.g. white ink. The opacifying layers are preferably substantially the same colour as one another (and are spatially uniform in colour), most preferably white or another light colour such as off-white or grey so that the multi-colour image 1100 will contrast well against it.

[0051] The multi-colour image 1100 in this example comprises four concentric elliptical rings whose colour varies from left to right across the image. While this image is depicted here, it will be appreciated that any multi-tonal or multi-colour image may be printed in accordance with the invention, including portraits, buildings, flags, and the like. The two print workings used to form this image are shown in magnification in Figures 4A and 4B.

[0052] Figure 4A shows a portion of the image 1100, including a portion of each of the four elliptical rings. In Figure 4A, it can be seen that the image is produced by the combination of two print workings: a first high-resolution print working 110 and a second lower resolution print working 120. In particular, it can be seen that the first print working 110 defines a first screen of screen elements 111 and the second print working 120 defines a second screen of screen elements 121. The individual screen elements can be seen in more detail in Figure 4B.

[0053] As shown more clearly in Figure 4B, the first print working 110 defines a screen of screen elements 111 that each have the form of a letter 'A' printed in violet. Each letter 'A' is composed of an arrangement of printed elements, i.e. dots 112, printed by the first digital print head. These dots 112 are printed across a grid of lattice points that correspond to the resolution of the first digital print head, i.e. 1200 DPI, and so the presence and absence of these printed dots 112 defines each letter 'A' and the gap separating each screen element from its neighbouring screen elements.

[0054] Similarly, Figure 4B shows that the second print working 120 defines a screen of screen elements 121 that each have the form of a letter 'D' printed in orange. Again, each letter 'D' is composed of an arrangement of printed elements, i.e. dots 122, printed by the digital print head. These dots 122 are printed across a grid of lattice points that correspond to the resolution of the second digital print head, i.e. 360 DPI, and the presence and absence of these dots across the grid defines each screen element in the screen. As is clear from Figure 4B, the spacing of the dots 122 making up each screen element 121 in the second screen differs from the spacing of the dots 112 making up each screen element 111 in the first screen and a viewer can check for this difference to authenticate the security document. Furthermore, in this example, the dots 122 have a significantly larger size than the dots 112 in the first working and again this can be visually checked to confirm authenticity.

[0055] As can be seen in Figure 4A, the screen elements 111, 121 of both screens vary in size across the image 1100. In particular, the screen elements become smaller from left to right across the image, while maintaining substantially the same shape and spacing. Fundamentally, this means that there will be fewer dots printed per unit area in the right-hand side of the image than in the left-hand side of the image. In this example, this means that more of the substantially white opacifying coating is visible on the right-hand side of the image. If the same proportion of printed element in the two workings is maintained across the image, then this reduction in number of printed elements per unit area will manifest

itself as a lightening in the tone of the image 1100. If the proportion of printed elements in the two workings changes from left to right across the image, e.g. going from a 3:1 ratio of printed elements in the first working 110 to printed elements in the second working per unit area to a ratio of 2:1, then the balance of the two colours will change across the image 1100, giving rise to a variation in perceived colour (i.e. the perceived colour will have less contribution from the violet ink and more contribution from the orange ink).

[0056] In order to authenticate the document of Figures 3A to 4B using only the digitally printed content, a viewer may first inspect the image 1100 to confirm that the correct multi-colour image is provided and that it features the expected colour variation. The user may then closely inspect the document to confirm that two different screens of screen elements are provided that vary across the document and that the elements of each screen are entirely formed by one working. That is, the viewer may check that all of the dots in each screen element are part of the same working and printed in the same colour and at the same resolution, e.g. rather than a contribution of dots from multiple CMYK inks printed by different heads. The user may then compare the two screens to confirm that the dots forming the respective sets of screen elements are at different resolutions and different dot sizes. Finally, the user may check the information content of the screen elements, i.e. the alphanumeric characters.

[0057] A second embodiment will now be described with reference to Figures 5A and 5B. Figures 5A and 5B show an alternative arrangement of two workings used to define the multi-colour image 1100. Here, the two workings 110, 120 define first and second substantially non-overlapping screens. In particular, in this embodiment, the workings define a series of concentric elliptical rings in the different colours, i.e. violet and orange.

[0058] The first print working 110 defines each violet ring in the multi-colour image 1100 and defines each using a screen of screen elements 111 that, again, each have the form of a letter 'A'. Each letter 'A' is composed of an arrangement of printed elements, i.e. dots 112, printed in violet by the first digital print head, as can be seen more clearly in Figure 5B. These dots 112 are printed across a grid of lattice points that correspond to the resolution of the first digital print head, i.e. 1200 DPI, and so the presence and absence of these printed dots 112 defines each letter 'A' and the gap separating each screen element from its neighbouring screen elements. The screen elements of this screen may vary in size from left to right across the image 1100 so that each violet ring varies in tone from left to right. That is, on the left-hand side of the image, the density of printed elements 112 will be higher than on the right-hand side and so the visibility of the substantially white opacifying coating will reduce from left to right. The result is a darker tone of violet on the left-hand side of the image and a lighter tone of violet in right-hand side of the image.

[0059] Similarly, Figure 5B shows that the second print working 120 defines each orange ring in the multi-colour image using a screen of screen elements 121 that each have the form of a letter 'D'. Again, each letter 'D' is composed of an arrangement of printed elements, i.e. dots 122, printed in orange by the digital print head. These dots 122 are printed across a grid of lattice points that correspond to the resolution of the second digital print head, i.e. 360 DPI, and the presence and absence of these dots across the grid defines each screen element in the screen. The screen elements 121 of this second screen may vary in size from left to right across the image 1100 so that each orange ring also varies in tone from left to right. Again, on the left-hand side of the image, the density of printed elements 122 will be higher than on the right-hand side and so the result will be a darker tone of orange on the left-hand side of the image and a lighter tone of orange in right-hand side of the image.

[0060] As is clear from Figure 5B, the spacing of the dots 122 making up each screen element 121 in the second screen differs from the spacing of the dots 112 making up each screen element 111 in the first screen and a viewer can check for this difference to authenticate the security document. The substantially non-overlapping nature of the screen elements in these screens ensures allows a viewer to more readily confirm that each screen element is composed of printed elements of only one colour, i.e. violet or orange, and not of a combination of printed elements, e.g. CMYK dots.

[0061] In the above examples, the variation in the screens that provide colour or tone variation is provided by varying the size of the screen elements. However, as mentioned above, variation in the shape and spacing of the screen elements may also be used, as well as varying the screen elements by varying the number of printed elements, size of printed elements and spacing of printed elements making up each screen element, although these will typically follow from varying the shape or size of the screen elements. Figures 6A and 6B illustrate a screen whose elements vary in shape, as well as number of printed elements and spacing of printed elements. This type of screen variation could be employed in either of the above embodiments instead of size variation.

[0062] Figure 6A shows a first working 110 defining a screen of screen elements 111 which vary in shape to produce tone or colour variation. As can be seen more clearly in the enlarged portion of Figure 6B, these screen elements are formed by printed elements 112, in this case violet dots printed at 1200 DPI. The screen elements on the top row of the grid of screen elements shown in Figure 6B have the shape of a letter 'A' and these change gradually towards the bottom row of the grid to a diamond shape. The average spacing of the printed elements also varies as the screen elements change shape, with the screen elements shaped as a letter 'A' having a closer average spacing of printed elements than the screen elements shaped as a diamond. The screen element in the top right of Figure 6B, for example, has a total of 21 dots with dots being arranged on the regular square grid of

lattice points to be horizontally and vertically adjacent to neighbouring dots. The screen element in the bottom left of Figure 6B has transitioned entirely to a diamond shape and has a total of nine dots arranged on the regular square grid of lattice points to be diagonally adjacent to their nearest neighbouring dots. As a result, this screen provides variation in shape and size of the screen elements, as well as in the number of printed elements and the spacing of printed elements making up each screen elements. These variations change the print density of the dots within the first working 110 and so may provide variation in tone and/or colour across an image.

[0063] Another image composed of multiple screens that may be printed on a security document according to the invention will now be described with reference to Figures 7 to 8C.

[0064] Figure 7 shows an image that may be printed by two digital print workings that are labelled in the drawings "Working - A" and "Working - B". The two workings each define a respective screen of elements, the form of which will be discussed in more detail below. The screen elements vary across the respective screens to provide multiple tones. The two workings partially overlap and combine to produce a high-quality multi-tonal image, here a portrait of Albert Einstein.

[0065] Figure 7 includes three enlarged portions (i), (ii) and (iii) showing magnified areas of the image 1100. Portion (i) shows a magnified area where only the first working 110 is present, defining a line screen, portion (iii) shows a magnified area where only the second working 120 is present, defining a two dimensional array of screen elements having the shape of a '£' symbol, and portion (ii) shows a magnified area of the overlapping combination of the two workings 110, 120 which produces the multi-tonal image.

[0066] Figures 8A to 8C show, schematically, further enlarged versions of portions (i), (ii) and (iii) in Figure 7 and demonstrate the formation and variation of the screen elements across the two workings 110, 120.

[0067] The first working 110, defines a line screen composed of diagonal lines 111 that vary in spacing across the screen in order to produce variation in tone of the image. The variation in spacing changes the number of printed elements 112 per unit area and so results in a change in tone. There may also be provided breaks in the lines for areas of even lighter tone. As can be seen in Figure 8A, each line is formed by an appropriate arrangement of printed elements, i.e. dots 112, printed at a first resolution, e.g. 1200 DPI. The second working, as can be seen in Figure 8C, defines a two-dimensional array, with each screen element 121 having the shape of a '£' symbol. Again, each screen element is formed by an appropriate arrangement of printed elements, i.e. dots 122, this time printed at a second resolution, e.g. 500 DPI. In this example, this size, and particularly the line weight, of the screen elements 121 of the second screen varies across the screen in order to provide the variation in tone of the image. This variation in line weight is generated by changing the dot size used to print each screen element. For example, the lowest line weight screen elements may be printed with drop sizes of 3.5 pl, with intermediate screen elements being printed at 6 pl and 10 pl and the highest line weight screen elements being printed with drop sizes of 18 pl. This may contrast with the first working, which may be printed with drop sizes of 2.4 pl, for example. Providing the same shape of screen elements formed using the same number of dots but with dots of different sizes changes the amount of ink per unit area and so results in a change in tone in the image.

[0068] As will be evident, in particular in Figure 8B, the first and second workings 110, 120 are printed at different resolutions and with different dot sizes (i.e. the dot size used in the first working doesn't correspond to any of the dot sizes printed in the second working), which can be distinctly seen by a viewer closely inspecting the security document.

[0069] In this embodiment, the first and second workings 110, 120 may be printed in inks having substantially the same colour under normal viewing conditions. However, for example, the ink used for the second working 120 may include a fluorescent pigment so that the document can be inspected under, for example, UV light, in order to enable a viewer to more clearly distinguish between the two workings and more clearly recognise the screen elements having the shape of a '£' symbol.

[0070] One of the advantages of providing a secure digitally printed security document is that the documents can individually vary in their printed content owing to the inherent flexibility of digital printing. One method by which screens can be customised for individual security documents will now be discussed with reference to the flow diagram of Figure 9.

[0071] In step S100 an image layer to be printed is received by the digital print press controller. A security document may be printed by providing a source image comprised of multiple layers, one layer corresponding to each digital print head. Where a multi-coloured image is to be printed, the different layers may correspond to different colour components of the image to be printed in the corresponding colours by the different digital print heads. This method will discuss only the customisation of one screen, i.e. printed by one digital print head, but it will be appreciated that each screen may be customised by performing a version of this method on each image layer corresponding to each digital print head. In step S100, the controller also receives a list of all possible screen element symbols that may appear in the screen. In the below example, the screen is customised with the serial number of the security document and so the possible screen element symbols include the digits 0-9; however, other documents, or even other screens in this document, may be customised with any manner of symbol, including letters, logos and icons.

[0072] In step S200, the image layer is divided into two-dimensional array of regions, with each region being of

a size so that one screen element will be depicted within the region. For example, the image layer may be divided into a series of square regions, each sized to be ten dots wide by ten dots high at the resolution of the digital print head that will print the screen. Each region is assigned one of a set of grey levels depending on the image content of the image layer in that region. For example, it may be established that the image will be printed using five different grey levels and the most appropriate grey level for each region will be selected from the five possible grey levels. A dithering process may also be applied to the grey level assignment to improve the image layer representation. Each region will map onto one of the digits in the serial number used to customise the screen. For example, the top left region may map onto the first digit in a serial number, with the region to the right being the next digit in the serial number, and so on, with the full range of serial number digits repeating across the array.

[0073] In step S300, the controller generates a dot pattern for each possible screen element symbol at each of the possible grey levels. Since five different grey levels are used in this example, five different dot pattern versions of each possible screen element symbol are produced, corresponding to the five grey levels. These dot patterns will typically involve a change in the number of printed elements and/or size of printed elements making up each screen element and will typically also involve a change in the size of the screen element itself, e.g. the line weight of the symbol; however the screen element shape should be generally consistent, as each needs to depict the same digit. In general, the different versions of each possible screen element symbol will correspond to a different total ink coverage within the ten dot by ten dot region for each symbol.

[0074] In step S400, the controller receives the serial number of the first document to be printed. This serial will comprise a unique arrangement of digits assigned to the security document.

[0075] In step S500, the controller selects the appropriate dot pattern for each region. For any region, firstly, the controller checks the serial number digit that needs to appear in that region. For example, if a region corresponds to the third digit in the serial number, and for this document that digit is an '8', then one of the dot patterns representing an '8' must be selected. Then, the controller checks the grey level of the region and selects the dot pattern for that particular digit that corresponds to this required grey level. By performing this process for each region across the image layer, the controller will build up a screen in which each screen element has a form that is determined based on the unique serial number of the security document, and a print density determined by the grey levels of the image to be printed.

[0076] In step S700, the controller checks if there are any more security documents to be printed. If there are more security documents to be printed, the method returns to step S400, at which the controller receives the serial number of the next document to be printed, before repeating steps S500 and S600 to generate the unique screen for the security document and print the screen onto the document substrate. Once there are no more security documents to be printed, the process ends.

[0077] The invention may be further understood by reference to the following numbered clauses, which define preferable combinations of features:

Clause 1. A digitally printed security document comprising: a security document substrate; a first digitally printed print working on a first surface of the substrate, the first print working comprising a first array of printed elements arranged according to a first grid of lattice points having a first pitch, the first array of printed elements defining a first screen of laterally distributed screen elements, each composed of multiple printed elements; and a second digitally printed print working on the first surface of the substrate, the second print working comprising a second array of printed elements arranged across a second grid of lattice points having a second pitch different from the first pitch, the second array of printed elements defining a second screen of laterally distributed screen elements, each composed of multiple printed elements, the second screen of laterally distributed screen elements being different than the first screen of laterally distributed screen elements; wherein the screen elements of at least one of the first and second screens vary across the respective screen in one or more of the size, shape, spacing, number of printed elements, size of printed elements and spacing of printed elements of each screen element to provide areas of different colour or tone defining at least part of a multi-colour or multi-tonal image.

Clause 2. A digitally printed security document according to clause 1, wherein the first and second screens of laterally distributed print element differ in the shape, size and/or spacing of the screen elements of the respective screens.

Clause 3. A digitally printed security document according to clause 1 or clause 2, wherein the screen elements of the first screen differ from the screen elements of the second screen in the number of printed elements, the size of printed elements and/or the spacing of printed elements making up each screen element.

Clause 4. A digitally printed security document according to any of the preceding clauses, wherein a plurality of the screen elements of the first screen have substantially the same shape, and/or wherein a plurality of the screen elements of the second screen have substantially the same shape, wherein preferably said shape of the screen elements of the second screen is different from said shape of the screen elements of the first screen.

Clause 5. A digitally printed security document according to any of the preceding clauses, wherein the screen elements of the first and/or second screen have the shape of one or more indicia carrying information, wherein preferably the screen elements define alphanumeric characters, symbols, logos and/or icons.

Clause 6. A digitally printed security document according to clause 5, wherein the screen elements of the first and second screens have the shape of indicia carrying different information, wherein preferably the screen elements define different sets or arrangements of alphanumeric characters, symbols, logos or icons.

Clause 7. A digitally printed security document according to clause 5 or clause 6, wherein the screen elements of at least one of the first and second screens have the shape of one or more indicia that vary in size and/or spacing across the screen to provide areas of different tone or colour.

Clause 8. A digitally printed security document according to any of clauses 5 to 7, wherein the screen elements of the first and/or second screen have the shape of one or more indicia carrying information relating to the digitally printed security document, such as serial number, denomination, currency, issue, bank and/or country information.

Clause 9. A digitally printed security document according to any of the preceding clauses, wherein at least some of the laterally distributed screen elements of the first second screen are spaced from the neighbouring screen elements of the first screen and/or wherein at least some of the laterally distributed screen elements of the second screen are spaced from the neighbouring screen elements of the second screen.

Clause 10. A digitally printed security document according to any of the preceding clauses, wherein a plurality, preferably each, screen element in the first and/or second screen includes a plurality of printed elements having a spacing corresponding to the respective first and/or second pitch of the first and/or second grid of lattice points.

Clause 11. A digitally printed security document according to any of the preceding clauses, wherein the screen elements of both of the first and second screens vary across the respective screen in one or more of the size, shape, spacing, number of printed elements, size of printed elements and spacing of printed elements of each screen element to provide areas of different colour or tone defining at least part of a multi-colour or multi-tonal image.

Clause 12. A digitally printed security document according to any of the preceding clauses, wherein the first screen of laterally distributed screen elements is provided across a first region and the second screen of laterally distributed screen elements is provided across a second region at least partially overlapping the first region.

Clause 13. A digitally printed security document according to clause 12, wherein one or more of the screen elements of the first screen differ from one or more, preferably each, of the screen elements of the second screen in size, shape and/or spacing of the screen elements where the first and second regions overlap.

Clause 14. A digitally printed security document according to clause 12 or clause 13, wherein one or more of the screen elements of the first screen overlap one or more of the screen elements of the second screen, said overlapping screen elements preferably differing in size, shape and/or spacing.

Clause 15. A digitally printed security document according to any of clauses 12 to 14, wherein the screen elements of at least one of the first and second screens vary in one or more of the size, shape, spacing, number of printed elements, size of printed elements and spacing of printed elements across the overlap of the first and second regions to provide areas of different colour or tone defining at least part of a multi-colour or multi-tonal image in the overlap of the first and second regions.

Clause 16. A digitally printed security document according to clause 15, wherein the screen elements of the first and second screens vary differently across the overlap of the first and second regions to provide areas of different colour or tone defining at least part of a multi-colour or multi-tonal image in the overlap of the first and second regions.

Clause 17. A digitally printed security document according to any of the preceding clauses, wherein the first digitally printed print working is printed in a first material, preferably a first ink, and the second digitally printed print working is printed in a second material, preferably a second ink, different from the first material.

Clause 18. A digitally printed security document according to clause 17, wherein the first and second materials have different optical characteristics.

Clause 19. A digitally printed security document according to clause 18, wherein the first material has a first colour and the second material has a second colour different from the first colour.

Clause 20. A digitally printed security document according to clause 19, wherein the screen elements of at least one of the first and second screens vary across the respective screen in one or more of the size, shape, spacing, number of printed elements, size of printed elements and spacing of printed elements of each screen element to provide areas of different colour defining at least part of a multi-colour image in the overlap of the first and second regions.

Clause 21. A digitally printed security document according to any of clauses 18 to 20, wherein the first and/or second inks are metallic inks, colour shifting inks, metameric inks, luminescent inks, fluorescent inks, phosphorescent inks, infrared-absorbing inks, thermochromic inks and/or photochromic inks.

Clause 22. A digitally printed security document according to any of the preceding clauses, wherein at least one of the first and second workings is printed in material having a colour that is not one of CMYK, and preferably wherein at least one of the first and second workings is printed in material having a colour that lies outside of the CMYK colour gamut.

Clause 23. A digitally printed security document according to any of the preceding clauses, wherein the first and/or second array of printed elements positively define the corresponding first and/or second screens.

Clause 24. A digitally printed security document according to any of the preceding clauses, the first grid of lattice points is a two-dimensional grid of lattice points defined by a first unit cell, and wherein the second grid of lattice points is a two-dimensional grid of lattice points defined by a second unit cell, wherein the first and second unit cells are different from one another.

Clause 25. A digitally printed security document according to any of the preceding clauses, wherein the first and second grids are each regular, square grids of lattice points, or rectangular grids of lattice points.

Clause 26. A digitally printed security document according to any of the preceding clauses, wherein the first grid of lattice points has a pitch in each of two orthogonal directions and wherein the second grid of lattice points has a pitch in each of two orthogonal directions, wherein preferably each pitch of the first grid of lattice points is different from both pitches of the second grid of lattice points.

Clause 27. A digitally printed security document according to any of the preceding clauses, wherein at least some of the printed elements of the first array of printed elements have a smallest lateral dimension smaller than, preferably 25% smaller than, more preferably 50% smaller than, a smallest lateral dimension of the printed elements of the second array of printed elements, and/or wherein at least some of the printed elements of the second array of printed elements have a smallest lateral dimension larger than, preferably 50% larger than, more preferably 100% larger than, a smallest lateral dimension of the printed elements of the first array of printed elements.

Clause 28. A digitally printed security document according to any of the preceding clauses, wherein the pitch of the first grid of lattice points corresponds to a print resolution of at least 600 DPI, preferably at least 900 DPI, more preferably at least 1200 DPI, in at least one direction.

Clause 29. A digitally printed security document according to any of the preceding clauses, wherein at least some of the printed elements of the first array of printed elements have a smallest lateral dimension of at most 200 micrometres, preferably at most 100 micrometres, more preferably at most 50 micrometres, most preferably at most 20 micrometres.

Clause 30. A digitally printed security document according to any of the preceding clauses, wherein the pitch of the second grid of lattice points corresponds to a print resolution of at most 600 DPI, preferably at most 360 DPI, further preferably at most 200 DPI, in at least one direction.

Clause 31. A digitally printed security document according to any of the preceding clauses, wherein at least some of the printed elements of the second array of printed elements have a smallest lateral dimension of at least 20 micrometres, preferably at least 50 micrometres, more preferably at least 100 micrometres most preferably at least 200 micrometres.

Clause 32. A digitally printed security document according to any of the preceding clauses, wherein the first print working comprises a printed element on each lattice point of the first grid of lattice points across at least a sub-region of the first region such that the first array of printed elements has the first pitch across said sub-region.

Clause 33. A digitally printed security document according to any of the preceding clauses, wherein the second print working comprises a printed element on each lattice point of the second grid of lattice points across at least a sub-region of the second region such that the second array of printed elements has the second pitch across the second sub-region.

Clause 34. A digitally printed security document according to any of the preceding clauses, wherein the security document substrate comprises a polymer substrate.

Clause 35. A digitally printed security document according to clause 33, wherein the polymer substrate is transparent and wherein the security document substrate further comprises one or more opacifying layers applied over at least part of the transparent substrate.

Clause 36. A digitally printed security document according to any of the preceding clauses, wherein the security document is a banknote, travellers cheque, certificate of authenticity, stamp, bond, tax disc, fiscal stamp, secure label, passport or voucher.

Clause 37. A plurality of security documents, each according to any of the preceding clauses.

Clause 38. A plurality of security documents according to clause 37, wherein the screen elements of at least one of the first and second screens of laterally distributed screen elements differ on each of the plurality of security documents.

Clause 39. A plurality of security documents clause 37 or clause 38, each security document according to at least any of clauses 5 to 8, wherein the screen elements of at least one of the first and second screens of laterally distributed screen elements differ in the information conveyed by the screen elements on each of the plurality of security documents.

Clause 40. A plurality of security documents according to any of clauses 37 to 39, wherein the first and second screens of laterally distributed screen elements are not registered to one another, such that the relative position of first and second screens varies between the security documents.

Clause 41. A method of digitally printing a security document, the method comprising: providing a security document substrate; digitally printing a first print working on a first surface of the substrate using a first print resolution such that a first array of printed elements is provided in accordance with the first print resolution, the first array of printed elements defining a first screen of laterally distributed screen elements, each composed of multiple printed elements; digitally printing a second print working on a first surface of the substrate using a second print resolution different from the first print resolution such that a second array of printed elements is provided in accordance with the second print resolution, the second array of printed elements defining a second screen of laterally distributed screen elements, each composed of multiple printed elements, the second screen of laterally distributed screen elements being different than the first screen of laterally distributed screen elements; wherein the screen elements of at least one of the first and second screens vary across the respective screen in one or more of the size, shape, spacing, number of printed elements, size of printed elements and spacing of printed elements of each screen element to provide areas of different colour or tone defining at least part of a multi-colour or multi-tonal image.

Clause 42. A method of digitally printing a security document according to clause 41, wherein digitally printing the first and/or second print working comprises inkjet printing the first and/or second print working.

Clause 43. A method of digitally printing a security document according to clause 41 or clause 42, wherein the first and second print workings are not printed in register with one another.

Clause 44. A method of digitally printing a security document according to any of clauses 41 to 43, comprising printing the first and second print workings in different print passes.

Clause 45. A method of digitally printing a security document according to any of clauses 41 to 44, further comprising receiving identifying information specific to the security document being printed, preferably unique to the security document printed, and printing at least one of the first and second workings such that the first and/or second screens comprises screen elements having the shape of one or more indicia corresponding to the identifying information.

Clause 46. A method of digitally printing a security document according to any of clauses 41 to 45, adapted to print a security document according to any of clauses 1 to 36 or adapted to print a plurality of security documents according to any of clauses 37 to 40.

Claims

1. A digitally printed security document comprising:

a security document substrate;
a first digitally printed print working on a first surface of the substrate, the first print working comprising a first array of printed elements arranged according to a first grid of lattice points having a first pitch, the first array of printed elements defining a first screen of laterally distributed screen elements, each composed of multiple

printed elements; and

a second digitally printed print working on the first surface of the substrate, the second print working comprising a second array of printed elements arranged across a second grid of lattice points having a second pitch different from the first pitch, the second array of printed elements defining a second screen of laterally distributed screen elements, each composed of multiple printed elements, the second screen of laterally distributed screen elements being different than the first screen of laterally distributed screen elements;

wherein the screen elements of at least one of the first and second screens vary across the respective screen in one or more of the size, shape, spacing, number of printed elements, size of printed elements and spacing of printed elements of each screen element to provide areas of different colour or tone defining at least part of a multi-colour or multi-tonal image.

2. A digitally printed security document according to claim 1, wherein the first and second screens of laterally distributed print element differ in the shape, size and/or spacing of the screen elements of the respective screens.

3. A digitally printed security document according to claim 1 or claim 2, wherein the screen elements of the first screen differ from the screen elements of the second screen in the number of printed elements, the size of printed elements and/or the spacing of printed elements making up each screen element.

4. A digitally printed security document according to any of the preceding claims, wherein a plurality of the screen elements of the first screen have substantially the same shape, and/or wherein a plurality of the screen elements of the second screen have substantially the same shape, wherein preferably said shape of the screen elements of the second screen is different from said shape of the screen elements of the first screen.

5. A digitally printed security document according to any of the preceding claims, wherein the screen elements of the first and/or second screen have the shape of one or more indicia carrying information, wherein preferably the screen elements define alphanumeric characters, symbols, logos and/or icons, wherein preferably the screen elements of the first and second screens have the shape of indicia carrying different information, wherein preferably the screen elements define different sets or arrangements of alphanumeric characters, symbols, logos or icons and/or wherein the screen elements of at least one of the first and second screens have the shape of one or more indicia that vary in size and/or spacing across the screen to provide areas of different tone or colour and/or wherein the screen elements of the first and/or second screen have the shape of one or more indicia carrying information relating to the digitally printed security document, such as serial number, denomination, currency, issue, bank and/or country information.

6. A digitally printed security document according to any of the preceding claims, wherein at least some of the laterally distributed screen elements of the first second screen are spaced from the neighbouring screen elements of the first screen and/or wherein at least some of the laterally distributed screen elements of the second screen are spaced from the neighbouring screen elements of the second screen.

7. A digitally printed security document according to any of the preceding claims, wherein a plurality, preferably each, screen element in the first and/or second screen includes a plurality of printed elements having a spacing corresponding to the respective first and/or second pitch of the first and/or second grid of lattice points.

8. A digitally printed security document according to any of the preceding claims, wherein the screen elements of both of the first and second screens vary across the respective screen in one or more of the size, shape, spacing, number of printed elements, size of printed elements and spacing of printed elements of each screen element to provide areas of different colour or tone defining at least part of a multi-colour or multi-tonal image.

9. A digitally printed security document according to any of the preceding claims, wherein the first screen of laterally distributed screen elements is provided across a first region and the second screen of laterally distributed screen elements is provided across a second region at least partially overlapping the first region, wherein preferably one or more of the screen elements of the first screen differ from one or more, preferably each, of the screen elements of the second screen in size, shape and/or spacing of the screen elements where the first and second regions overlap, and/or wherein one or more of the screen elements of the first screen overlap one or more of the screen elements of the second screen, said overlapping screen elements preferably differing in size, shape and/or spacing, and/or wherein the screen elements of at least one of the first and second screens vary in one or more of the size, shape, spacing, number of printed elements, size of printed elements and spacing of printed elements across the overlap of the first and second regions to provide areas of different colour or tone defining at least part of a mul-

ti-colour or multi-tonal image in the overlap of the first and second regions.

10. A digitally printed security document according to any of the preceding claims, wherein the first digitally printed print working is printed in a first material, preferably a first ink, and the second digitally printed print working is printed in a second material, preferably a second ink, different from the first material, wherein preferably the first and second materials have different optical characteristics, wherein further preferably the first material has a first colour and the second material has a second colour different from the first colour, wherein most preferably the screen elements of at least one of the first and second screens vary across the respective screen in one or more of the size, shape, spacing, number of printed elements, size of printed elements and spacing of printed elements of each screen element to provide areas of different colour defining at least part of a multi-colour image in the overlap of the first and second regions.

11. A digitally printed security document according to any of the preceding claims, wherein at least some of the printed elements of the first array of printed elements have a smallest lateral dimension smaller than, preferably 25% smaller than, more preferably 50% smaller than, a smallest lateral dimension of the printed elements of the second array of printed elements, and/or wherein at least some of the printed elements of the second array of printed elements have a smallest lateral dimension larger than, preferably 50% larger than, more preferably 100% larger than, a smallest lateral dimension of the printed elements of the first array of printed elements.

12. A digitally printed security document according to any of the preceding claims, wherein the pitch of the first grid of lattice points corresponds to a print resolution of at least 600 DPI, preferably at least 900 DPI, more preferably at least 1200 DPI, in at least one direction, and/or wherein the pitch of the second grid of lattice points corresponds to a print resolution of at most 600 DPI, preferably at most 360 DPI, further preferably at most 200 DPI, in at least one direction.

13. A plurality of security documents, each according to any of the preceding claims, wherein the screen elements of at least one of the first and second screens of laterally distributed screen elements differ on each of the plurality of security documents.

14. A method of digitally printing a security document, the method comprising:

providing a security document substrate;
digitally printing a first print working on a first surface of the substrate using a first print resolution such that a first array of printed elements is provided in accordance with the first print resolution, the first array of printed elements defining a first screen of laterally distributed screen elements, each composed of multiple printed elements;
digitally printing a second print working on a first surface of the substrate using a second print resolution different from the first print resolution such that a second array of printed elements is provided in accordance with the second print resolution, the second array of printed elements defining a second screen of laterally distributed screen elements, each composed of multiple printed elements, the second screen of laterally distributed screen elements being different than the first screen of laterally distributed screen elements;
wherein the screen elements of at least one of the first and second screens vary across the respective screen in one or more of the size, shape, spacing, number of printed elements, size of printed elements and spacing of printed elements of each screen element to provide areas of different colour or tone defining at least part of a multi-colour or multi-tonal image.

15. A method of digitally printing a security document according to claim 14, further comprising receiving identifying information specific to the security document being printed, preferably unique to the security document printed, and printing at least one of the first and second workings such that the first and/or second screens comprises screen elements having the shape of one or more indicia corresponding to the identifying information.

Fig. 1

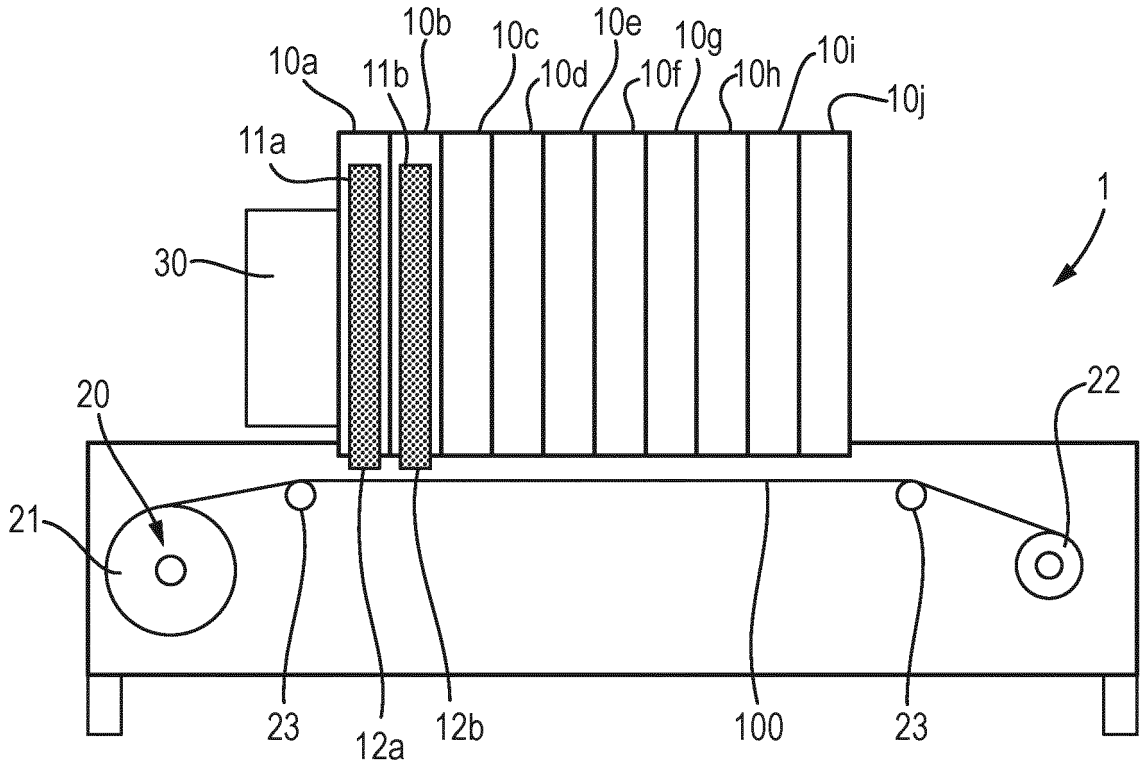

10a
11b
10b
10c
10d
10e
10f
10g
10h
10i
10j
11a
1
30
20
22
21
23
12a
12b
100
23

Fig. 2

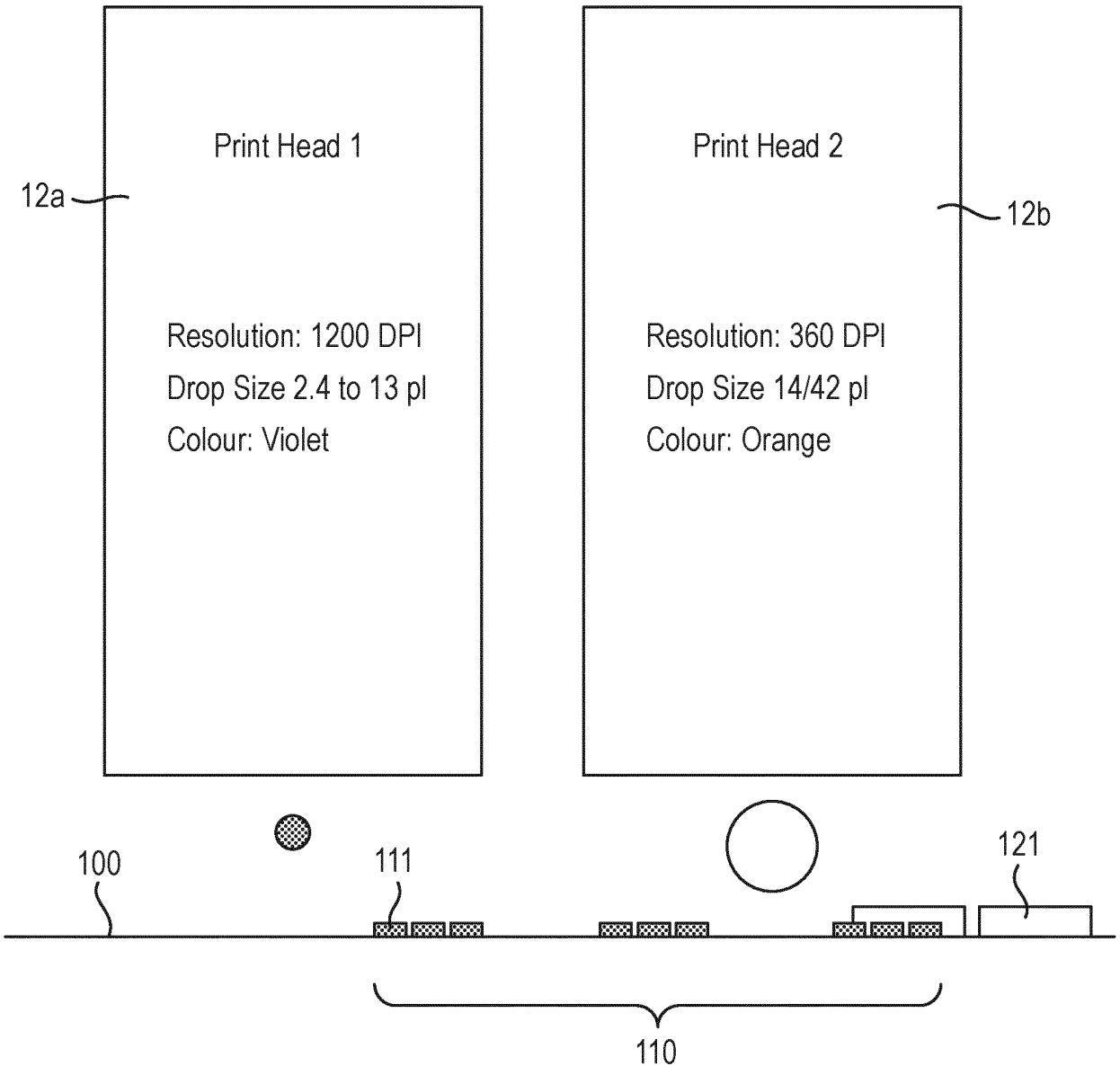

Print Head 1
12a
Resolution: 1200 DPI
Drop Size 2.4 to 13 pl
Colour: Violet
Print Head 2
12b
Resolution: 360 DPI
Drop Size 14/42 pl
Colour: Orange
100
111
121
110

Fig. 3A

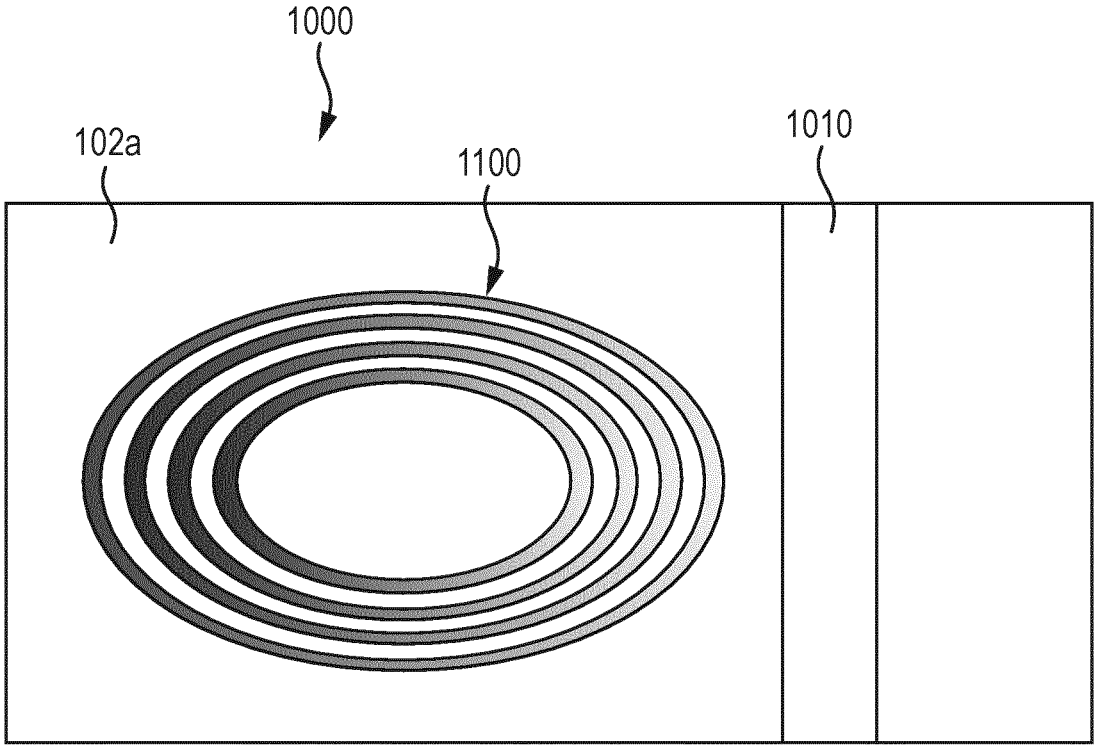


Fig. 3B

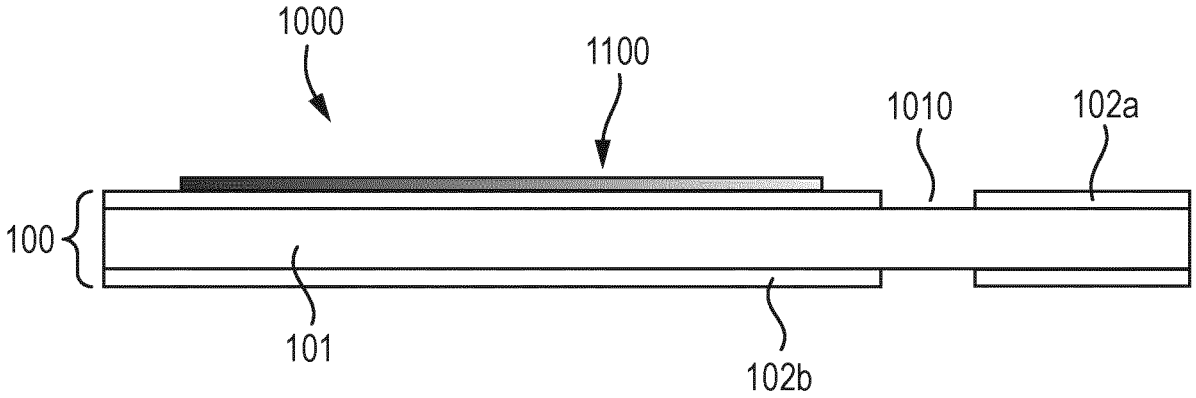


Fig. 4A

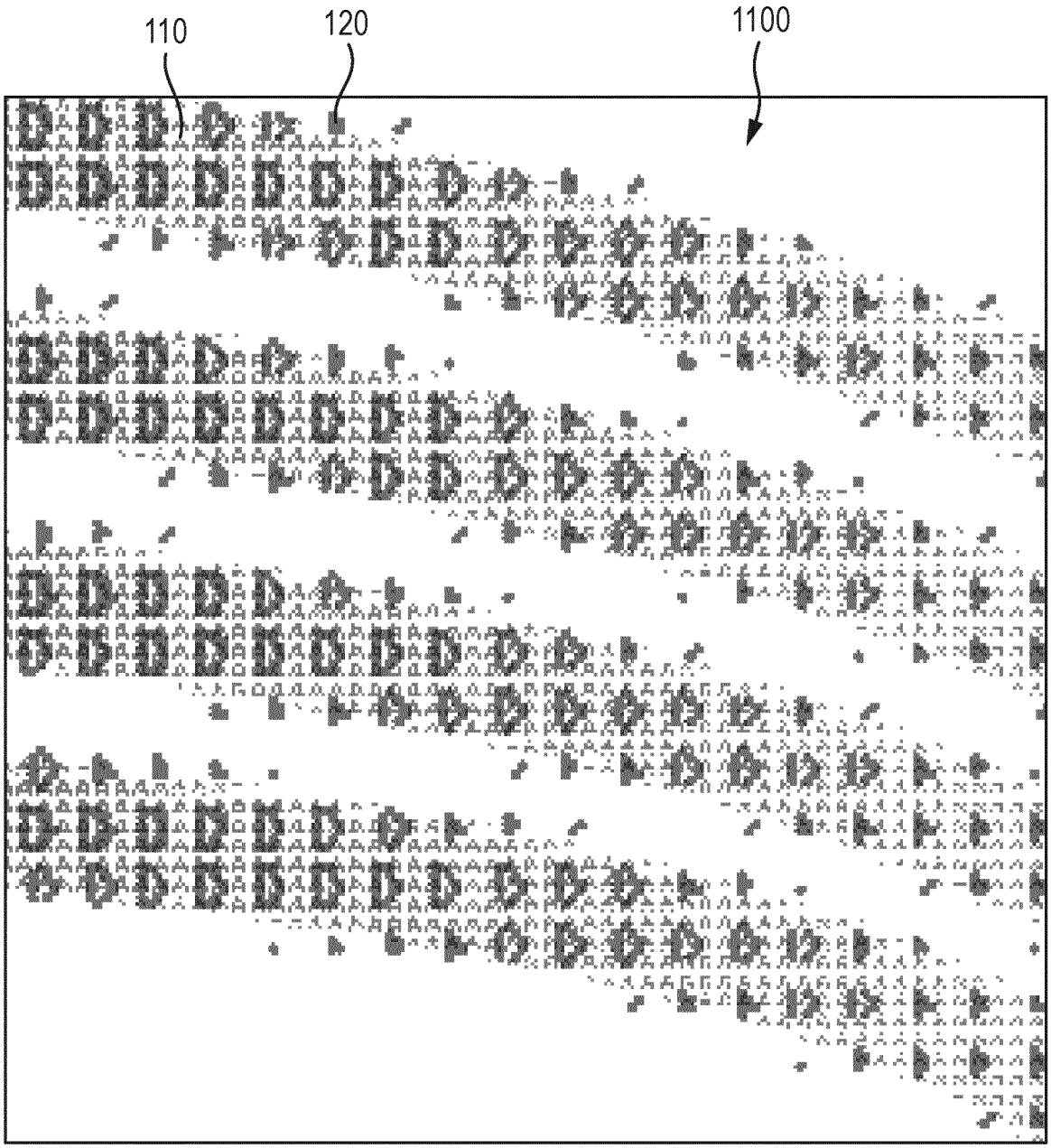


Fig. 4B

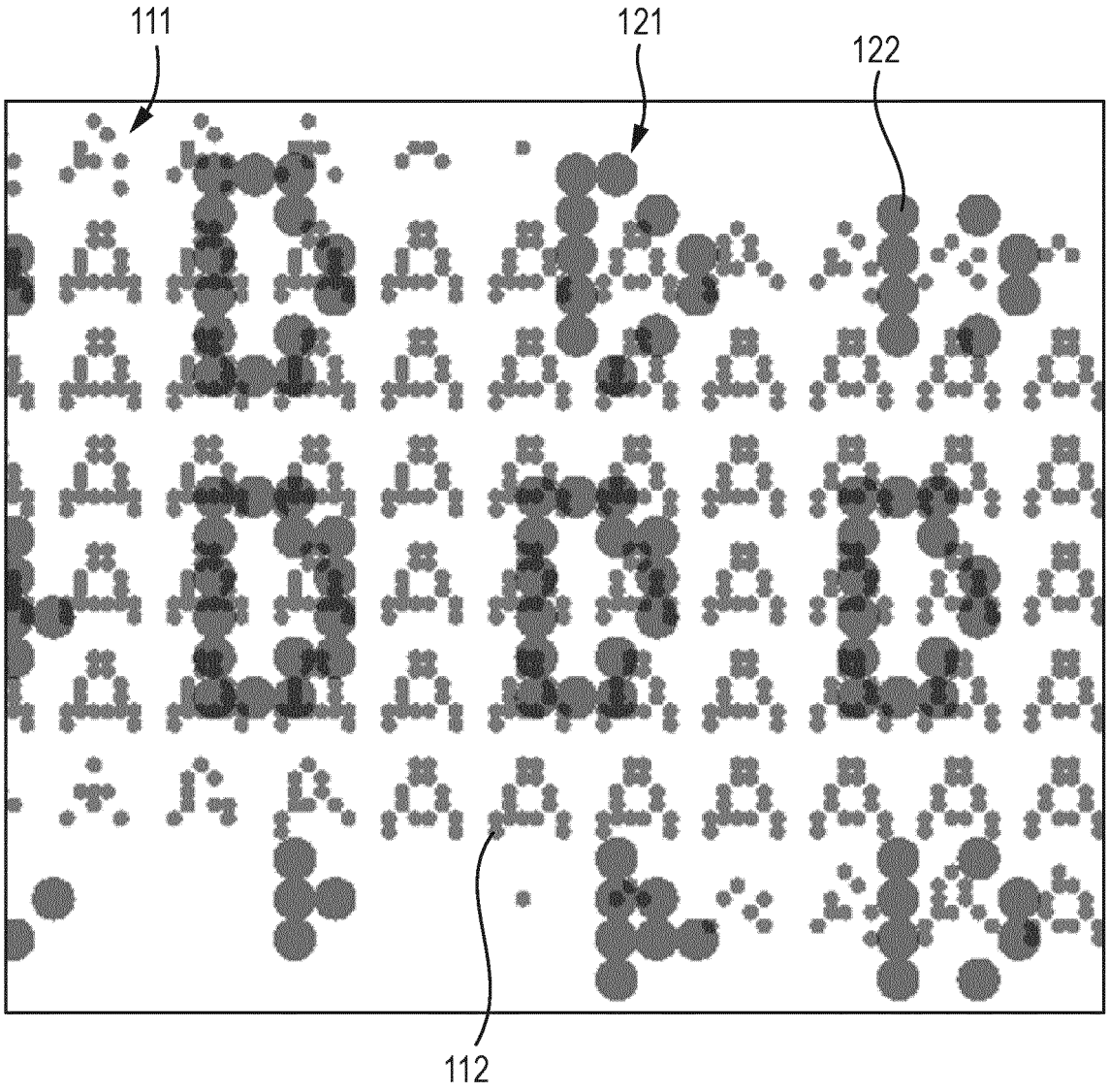


Fig. 5A

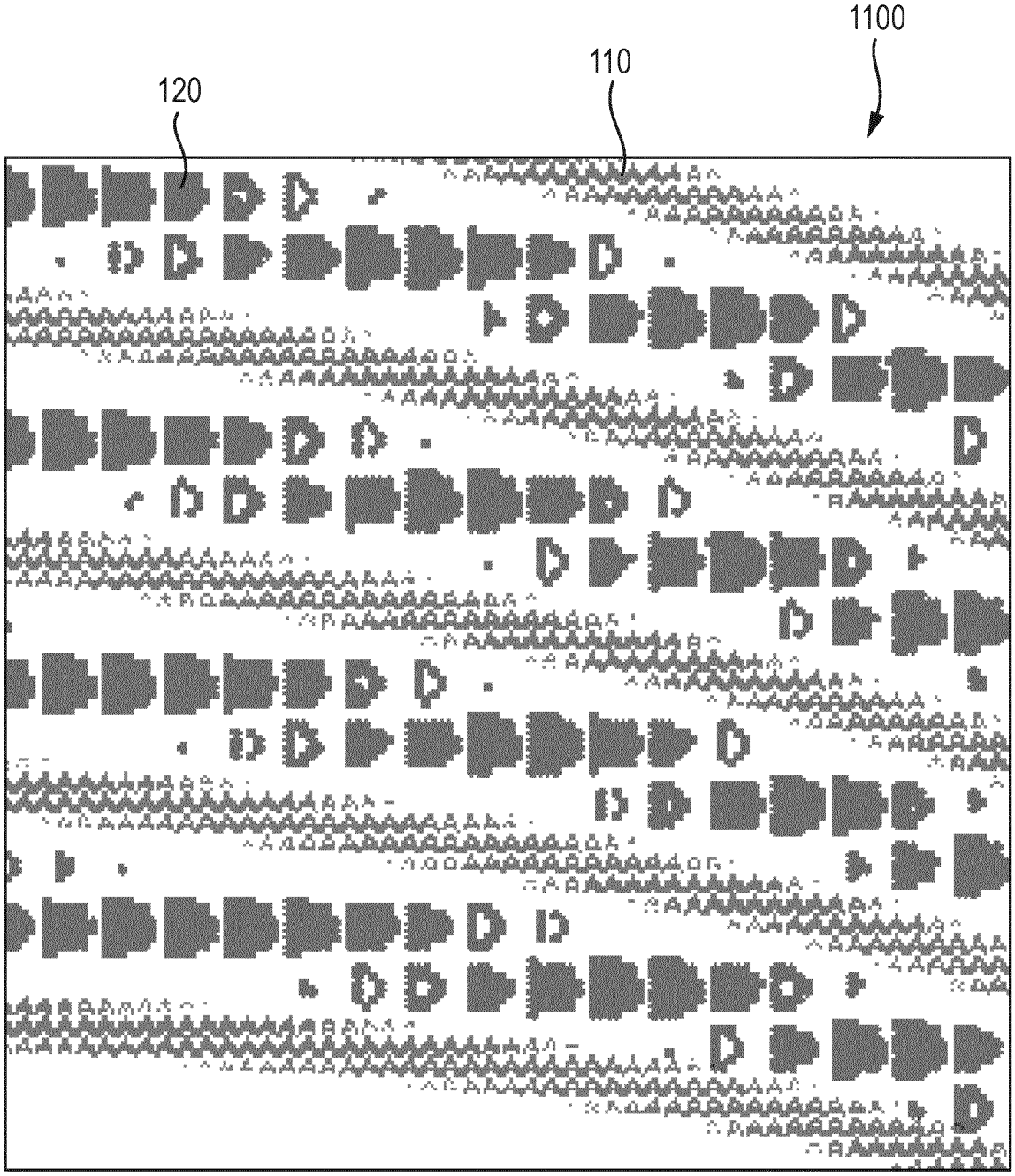


Fig. 5B

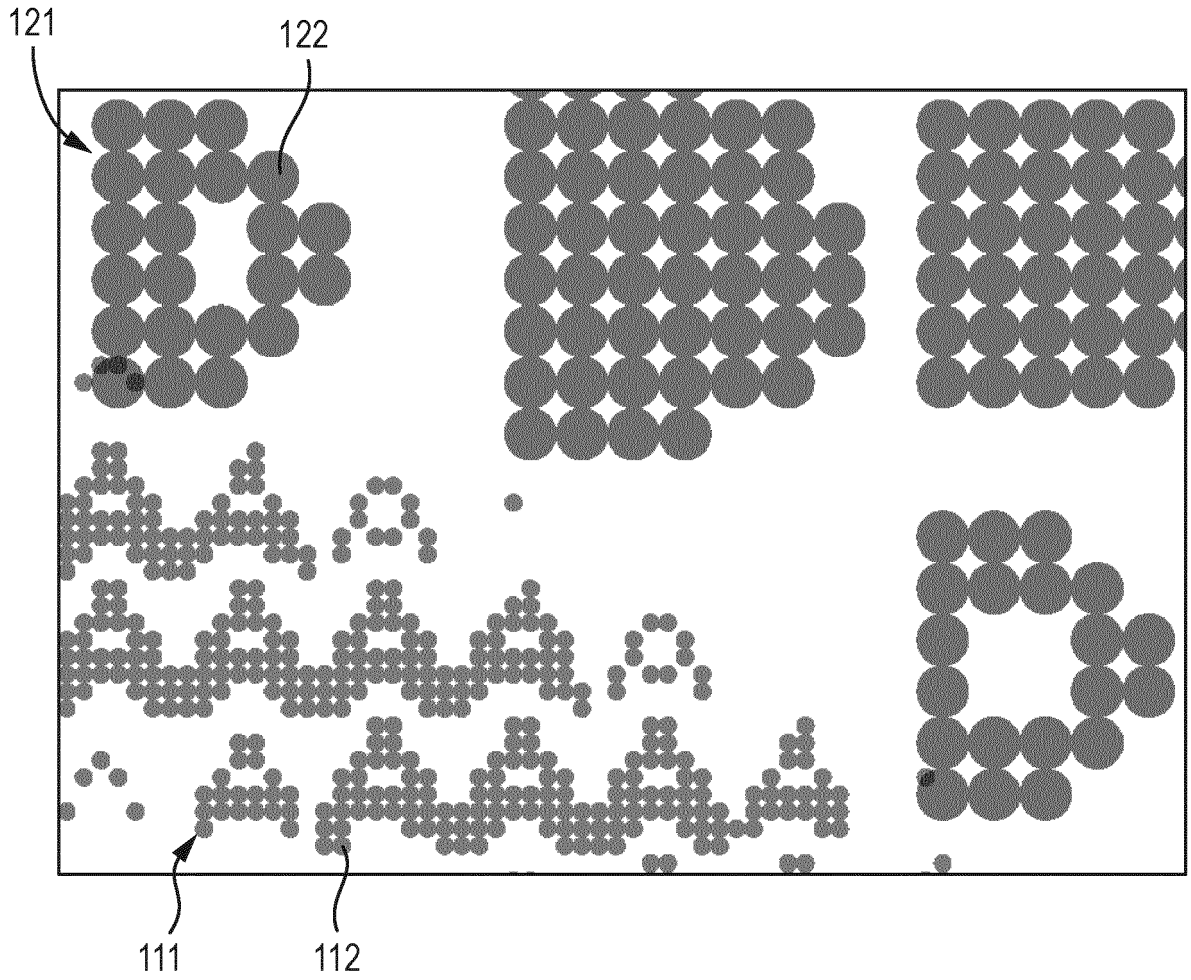


Fig. 6A

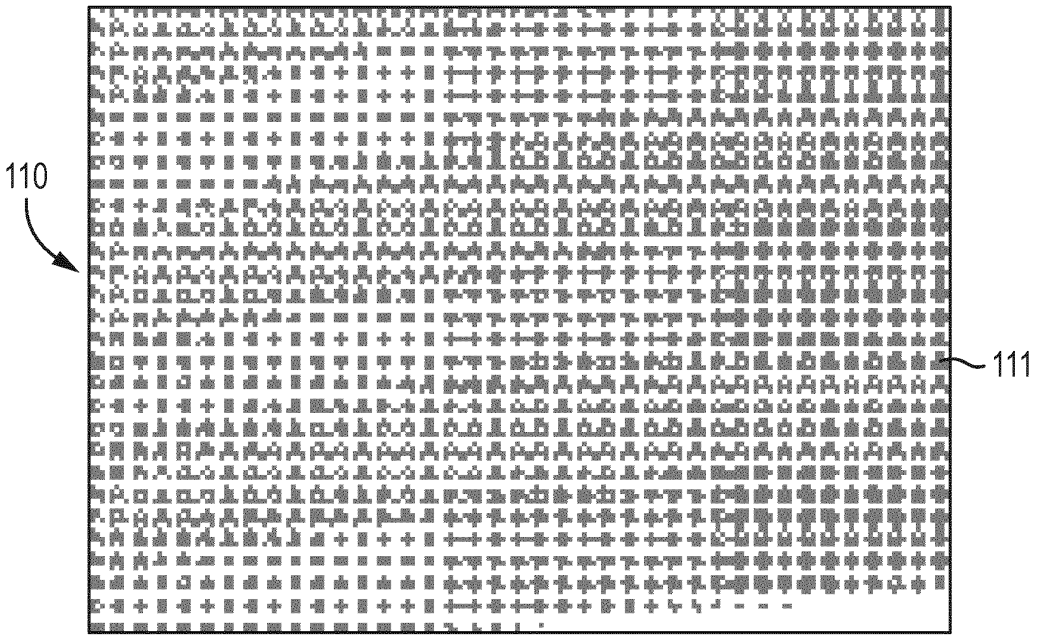


Fig. 6B

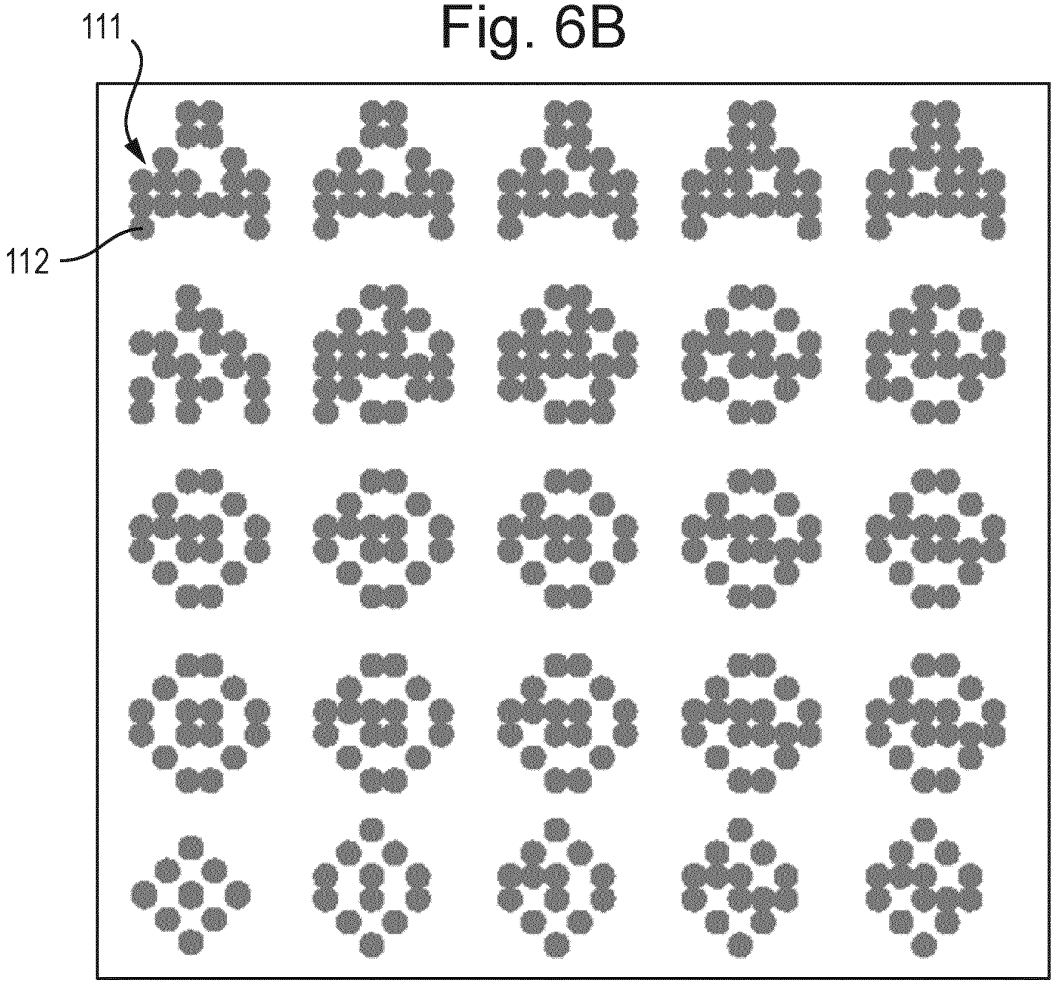


Fig. 7

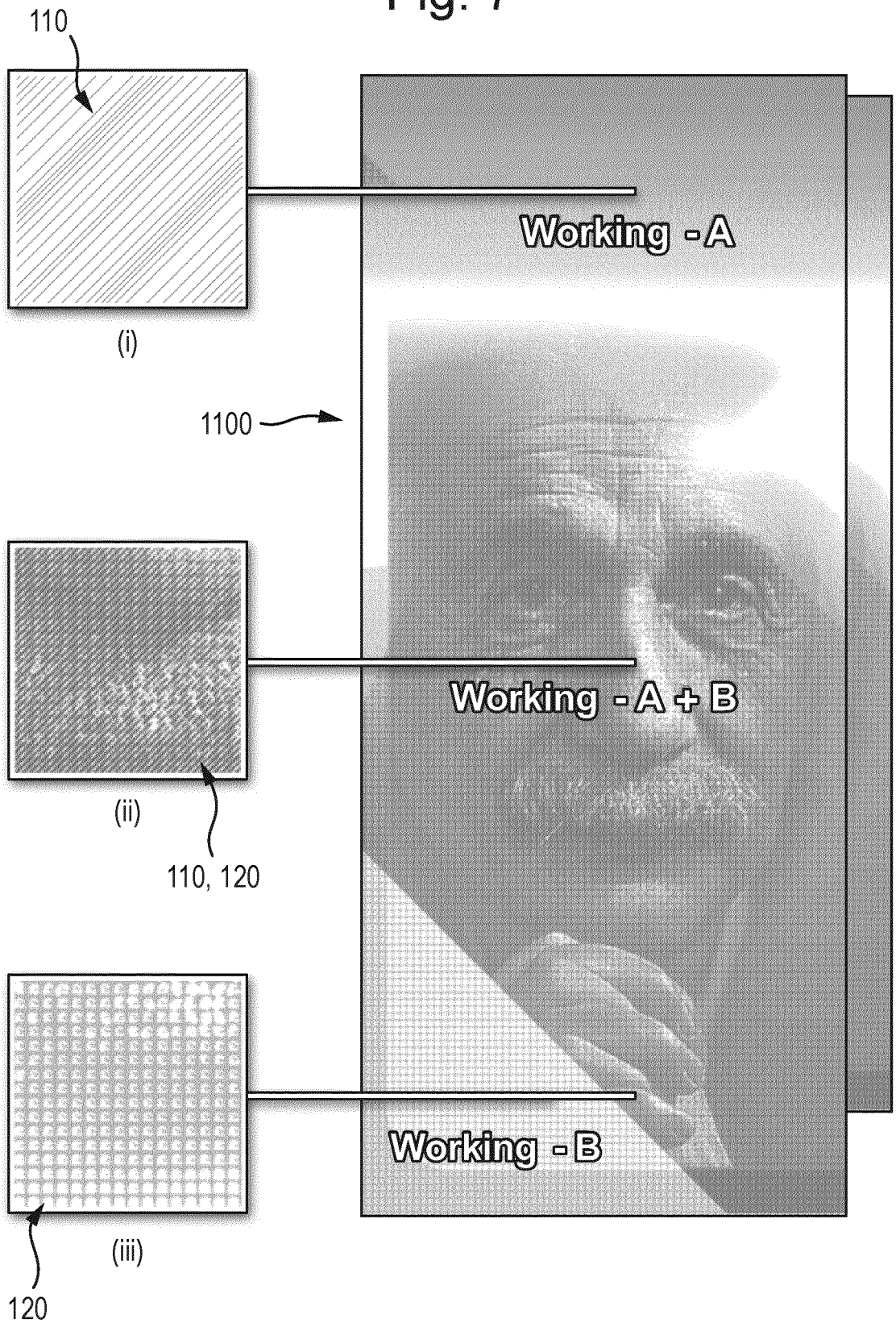


Fig. 8A

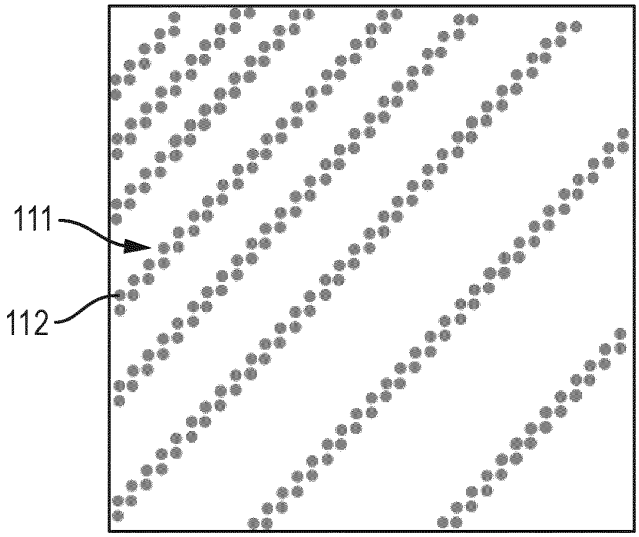


Fig. 8B

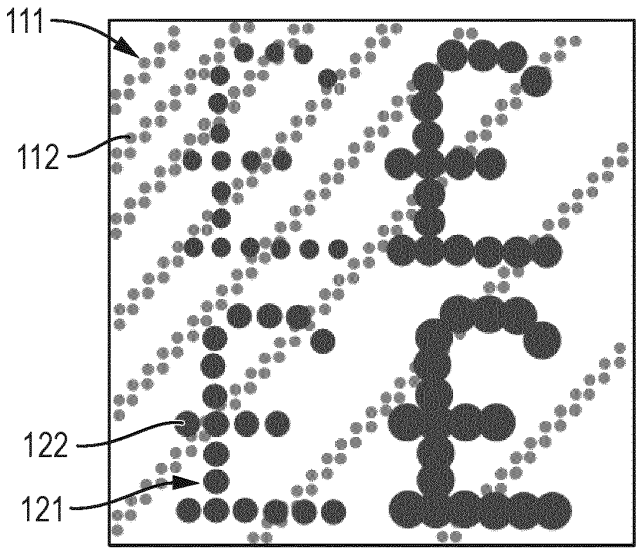


Fig. 8C

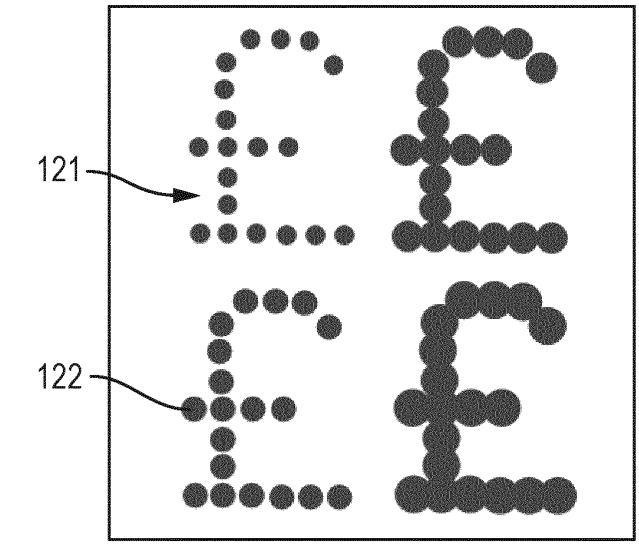
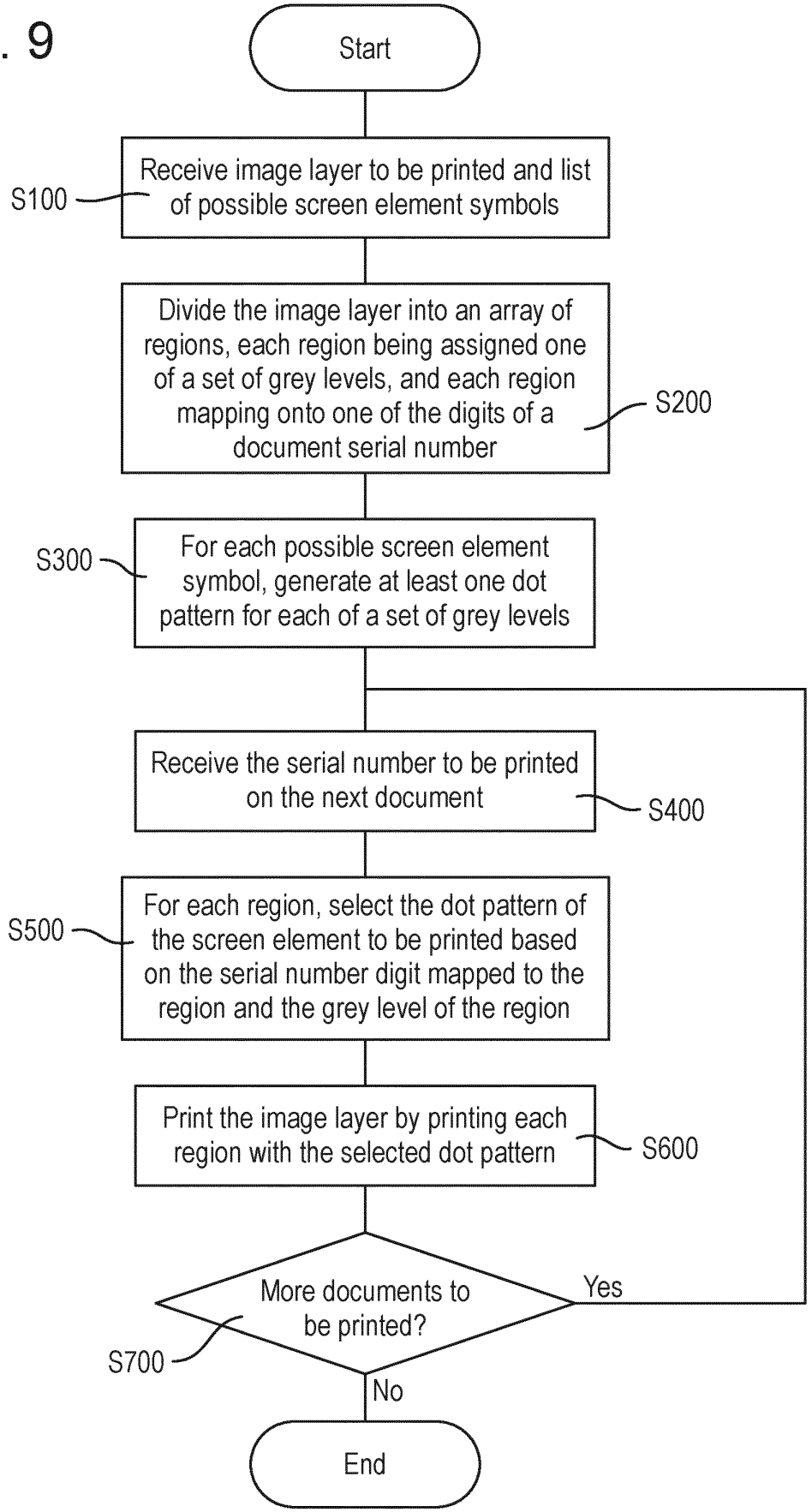


Fig. 9


Start
Receive image layer to be printed and list of possible screen element symbols
S100
Divide the image layer into an array of regions, each region being assigned one of a set of grey levels, and each region mapping onto one of the digits of a document serial number
S200
For each possible screen element symbol, generate at least one dot pattern for each of a set of grey levels
S300
Receive the serial number to be printed on the next document
S400
For each region, select the dot pattern of the screen element to be printed based on the serial number digit mapped to the region and the grey level of the region
S500
Print the image layer by printing each region with the selected dot pattern
S600
More documents to be printed?
S700
Yes
No
End

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 21 16 9338

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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A	EP 2 821 859 A1 (CEAG COMPTOIR EUROPÉEN DES ARTS GRAPHIQUES SARL [FR]) 7 January 2015 (2015-01-07) * figure 3 * -----	1,14	
A	WO 2015/095976 A1 (ORELL FÜSSLI SICHERHEITSDRUCK AG [CH]) 2 July 2015 (2015-07-02) * figures 6a,6b * -----	1,14	

TECHNICAL FIELDS SEARCHED (IPC)

B42D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	10 November 2021	Langbroek, Arjen

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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10-11-2021

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- Digital Color Imaging Handbook. CRC Press, 2003, 30-32 **[0024]**