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(54) **Personalization of physical media by selectively revealing and hiding pre-printed color pixels**

(57) Personalization of identity card by producing a colored fluorescent image thereon by selectively exposing photon-sensitive layers on the card to change between transparent and opaque thereby selectively revealing opaque colors from the photon-sensitive layer or from a printed substrate. Other systems and methods are disclosed.

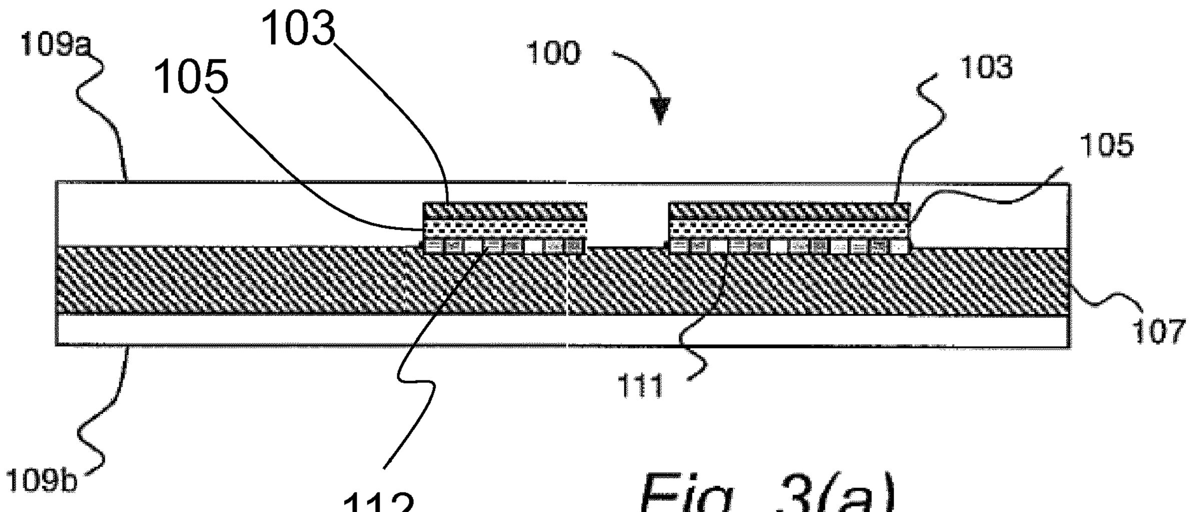

Fig. 3(a)

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Description

FIELD

[0001] The present invention relates generally to personalization of secure documents and more particularly to personalization by producing an image on a document.

BACKGROUND

[0002] Many forms of physical media require both mass-production and end-user personalization. For example, identity cards may need to be produced for very large population pools, yet every individual card has to uniquely identify the person carrying the card. The high-volume manufacturing phase may be performed on relatively expensive equipment because the equipment cost may be amortized over very large production runs. On the other hand, the end-user personalization may be preferably carried out at customer locations in relatively low volumes, thus, requiring much lower equipment costs.

[0003] For many identity cards, security of all information on the card, whether digitally recorded or physical features of the card, is of paramount importance. The security is sometimes tied to some features that reveal whether the media has physically been tampered with. One mechanism for thwarting attempts to tamper with identity cards is lamination. By securing the physical media in a lamination layer that may not delaminated without destroying the physical pristineness of the media goes very far to protect the security integrity of media.

[0004] One very important mechanism for tying an individual to an identity object is the placement of a person's photograph on the identity object. Driver's licenses, passports, identity cards, employee badges, etc., all usually bear the image of the individual to whom the object is connected.

[0005] Laser engraving provides one prior art technique for personalizing an identity card post-issuance with a photograph. Figure 1 is a perspective-exploded view of the various layers that make up such a prior art identity card 50. The identity card 50 may include a laser-engravable transparent polycarbonate layer 57. By selectively exposing an image area on the card with a laser, specific locations in the polycarbonate layer 57 may be rendered black, thereby producing a gray-scale image.

[0006] Traditionally polycarbonate (PC) ID products have been personalized using laser-engraving technology. This is based on a laser beam heating carbon particles inside specific polycarbonate layers to the extent that the polycarbonate around the particle turns black. While the particles could be chosen to be something else than carbon, it is the intrinsic property of polycarbonate that creates the desired contrast and number of gray levels to produce, for example, a photograph. The gray tone is controlled by the laser power and speed of scanning across the document. This technology is standard on the ID market. However, a limitation of this technique is that color images may not be produced in that manner.

[0007] In certain markets and applications it is desirable to have identity cards with color images.

[0008] Traditionally color photographs have been placed in identity cards using Dye Diffusion Thermal Transfer (D2T2) technology, which has been available for PVC and PET products. Recently the development in the D2T2 technology has made it possible to color-personalize also polycarbonate cards. This technology requires a smooth printed surface and the printed image must be shielded with an overlay film, which can also be holographic type.

[0009] A drawback to surface printed color personalization is that it is not as secure as the laser engraved photos and data that are situated inside the polycarbonate layer structure as illustrated in Figure 1.

[0010] In another prior art alternative, a color image may be produced using digital printing before the product is collated. This allows for high quality images placed on identity cards. Yet this technology has many drawbacks: the personalization and card body manufacturing must happen in the same premises, which furthermore typically have to be in the country of document issuance because governmental authorities dislike sending civil register data across borders, the color printed photographs prevent the PC layers from fusing to each other, and if any of the cards on a sheet is maculated in further production steps, the personalized card must be reproduced from the beginning of the process leading to a highly complicated manufacturing process.

[0011] US Pat. No. 7,368,217 to Lutz et al., Multilayer Image, Particularly a Multicolor Image, May 6, 2008 describes a technique in which color pigments are printed on collated sheets and each color may be bleached to a desired tone using a color sensitive laser.

[0012] In order to further secure such documents, it is known to produce one image on the document as described above and to reproduce somewhere else on the document a printed coded area which represents the same image but in a coded way.

[0013] However, in order to verify that the apparent image and the coded area correspond, sophisticated and expensive material for un-coding is necessary for the personal in charge of an identity check and the identity verification process is slowed down.

[0014] It is also known to produce a fluorescent image on an identification document like in US 2005/0161512. However, under visible light, such a fluorescent image is not visible at all for the personal in charge of an identity check and it is likely that the check of such a security item is omitted. In addition, the image is surface printed showing therefore the above mentioned drawbacks of surface printed images that are visible under exposure of visible light.

[0015] US 8314828 in the name of the assignee of the present patent application discloses a method for personalization of an identity card by producing a color image thereon by selectively exposing photon-sensitive layers on the card to change between transparent and opaque thereby revealing opaque colors from the photon-sensitive layer. The content of US 8314828 is incorporated by reference to the present application.

[0016] From the foregoing it will be apparent that there is a need to provide for supplemental personalized security items on identity card that may be checked without complex processing material.

SUMMARY OF THE INVENTION

[0017] The invention relates to a method for producing a colored fluorescent image when exposed to UV light in an image area on a physical media, comprising:

- printing a fluorescent print-pixel pattern on a substrate surface wherein the print-pixel pattern comprises a plurality of fluorescent print-pixels, each fluorescent print-pixel composed of a plurality of differently- colored fluorescent sub-pixels that emit in a predetermined wavelength range when exposed to UV light;

- covering the print-pixel pattern with at least one photon-sensitive layer wherein each photon-sensitive layer is in one of a plurality of states wherein each photon-sensitive layer is alterable at selected locations from one of two states to another state of two states;
- altering the state of at least one of the at least one photon-sensitive layers in a selected pattern across the physical media thereby selectively revealing a selected subset of sub-pixels and portions of photon-sensitive layers corresponding to other sub-pixels thereby producing an image composed of the revealed sub-pixels and photon-sensitive layer portions corresponding to other sub-pixels.

[0018] The invention also relates to a method for producing on a physical media a first image in a first image area and a second image in a second image area, where the first image is a colored image under exposure to visible light and the second image is a gray image under exposure to visible light and a colored image under exposure to UV light, comprising:

- printing a first print-pixel pattern and a second print-pixel pattern on a substrate surface wherein the first print-pixel pattern comprises a plurality of visible print-pixels and the second print-pixel pattern comprises a plurality of fluorescent print-pixels, each visible print-pixel composed of a plurality of differently colored sub-pixels that absorb and/or reflect light in a predetermined wavelength range when exposed to visible light; each fluorescent print-pixel composed of a plurality of differently- colored fluorescent sub-pixels that emit in a predetermined wavelength range when exposed to UV light;
- covering the first and the second print-pixel pattern with at least one photon-sensitive layer wherein each photon-sensitive layer is in one of a plurality of states wherein each photon-sensitive layer is alterable at selected locations from one of two states to another state of two states;

altering the state of at least one of the at least one photon-sensitive layers in a selected pattern across the physical media thereby selectively revealing a selected subset of sub-pixels and portions of photon- sensitive layers corresponding to other sub-pixels thereby producing an image composed of the revealed sub-pixels and photon-sensitive layer portions corresponding to other sub-pixels

[0019] According to one aspect, a first photon-sensitive layer is visually opaque and transforms into visually transparent upon exposure to photons of a first selected wavelength and intensity; wherein a second photon-sensitive layer is visually transparent and transforms into visually opaque upon exposure to photons of a second selected wavelength and intensity; wherein a first selected portion of the first photon-sensitive layer is exposed to reveal sub-pixels on the surface or any photon-sensitive layers between the print-pixel pattern located on the surface and the first photon-sensitive layer; and wherein a second selected portion of the second photon-sensitive layer is exposed to occlude sub-pixels on the surface and any photon-sensitive layers between the surface the second photon- sensitive layer.

[0020] According to another aspect, the at least one photon-sensitive layer transforms from opaque white into visually transparent.

[0021] According to a further aspect, the second photon-sensitive layer transforms from visually transparent into opaque black.

[0022] Moreover, the second photon- sensitive layer may be positioned in between the first photon-sensitive layer and the print-pixel pattern located on the substrate surface.

[0023] The method may comprise:

- revealing a colored fluorescent sub-pixel by exposing an area of the first photon-sensitive layer located above the colored sub-pixel to be revealed to photons of the first wavelength and intensity;
- and creating a black sub-pixel at a particular location by revealing an area of the second photon- sensitive layer corresponding to the particular location by exposing an area of the first photon-sensitive layer corresponding to the particular location to photons of the first wavelength and intensity and darkening the area of second photon-sensitive layer corresponding to the particular location by exposing the area of the second photon- sensitive layer also corresponding to the particular location to photons of the second wavelength and intensity.

[0024] The first photon-sensitive layer is for example a white bleachable ink.

[0025] The method may further comprise a step of fixing the selected exposed portions of the photon-sensitive layers by an additional exposure step.

[0026] The method may further comprise a step of fixing the selected exposed portions of the photon-sensitive layer by exposing a portion of the image area of the physical media to UV light.

[0027] The method may comprise a step of fixing the selected subset of sub-pixels of the photon-sensitive layer by exposing the selected subset of sub-pixels to heat.

[0028] According to one aspect, the alteration of a photon-sensitive layer is due to heat produced by photon exposure.

[0029] The altering step may comprise revealing sub-sub- pixels of individual sub-pixels thereby providing varying fluorescent color intensities for different sub-pixels in the pixel pattern.

[0030] In case each sub-pixel comprises a plurality of sub-sub- pixels, the step of altering the state of at least one of the at least one photon- sensitive layers may comprise the step of revealing a subset of the sub-sub-pixels of any sub-pixel.

[0031] According to another aspect, the method further comprises the step of determining which sub-sub-pixels to reveal from a corresponding pixel in a digital image.

[0032] The step of determining which sub-sub-pixels to reveal is for example based on the brightness of the corresponding pixel in the digital image and the hue of the pixel in the digital image.

[0033] The step of determining which sub-sub-pixels to reveal may be based on contrast transitions in the digital image.

[0034] The invention also relates to a medium personalizable by selective exposure to photons, comprising:

a fluorescent print-pixel pattern layer having a fluorescent print-pixel pattern comprising a plurality of fluorescent print-pixels, each fluorescent print-pixel composed of a plurality of differently- colored fluorescent sub-pixels that emit in a predetermined wavelength range when exposed to UV light; at least one photon-sensitive layer composed of a photon-sensitive material that transitions from a first state to a second state upon exposure to photons of a first wavelength and intensity.

[0035] The invention further relates to a medium personalizable by selective exposure to photons, comprising:

a print pixel pattern layer having a first the print-pixel pattern and a second print-pixel pattern, the first print-pixel pattern comprising a plurality of visible print-pixels, each visible print-pixel composed of a plurality of differently colored sub-pixels that absorb and /or reflect visible light in a predetermined wavelength range when exposed to visible light; the second print pixel pattern comprising a plurality of fluorescent print-pixels, each fluorescent print-pixel composed of a plurality of differently- colored fluorescent sub-pixels that emit in a predetermined wavelength range when exposed to UV light; at least one photon-sensitive layer composed of a photon-sensitive material that transitions from a first state to a second state upon exposure to photons of a first wavelength and intensity.

[0036] According to one aspect the at least one photon-sensitive material comprises: a transparent layer covering the pixel pattern and composed of a photon-sensitive material that transitions to some level of opaqueness upon being exposed to photons of the first wavelength and intensity.

[0037] According to another aspect, the at least one photon-sensitive material comprises: an opaque layer covering the fluorescent pixel pattern and composed of a photon- sensitive material that transitions to being transparent upon being exposed to photons of a second wavelength and intensity.

[0038] The transparent layer is for example a laser-engravable carbon-doped polycarbonate layer.

[0039] The opaque layer may be a bleachable ink.

[0040] The opaque layer is for example selectively removable by exposure to photons of particular wavelength and intensity.

[0041] According to a further aspect, the fluorescent print-pixel pattern is located on a surface of a substrate and between the surface of the substrate and a photon-sensitive layer.

[0042] According to another aspect, the fluorescent print-pixel-pattern layer is photon-sensitive and wherein a photon- sensitive layer is located between the fluorescent print-pixel-pattern layer and the substrate.

[0043] The medium personalizable may further comprise at least one lamination layer covering the at least one photon- sensitive layer and the fluorescent print-pixel-pattern layer.

[0044] The invention also relates to an apparatus for producing an image in an image area on a medium having a substrate with a surface printed with a fluorescent print-pixel pattern when exposed to UV light and having at least one photon-sensitive layer covering the fluorescent print-pixel pattern and wherein each photon- sensitive layer is in one of a plurality of states wherein each photon-sensitive layer is alterable at selected locations from one of two states to another state of two states, the apparatus comprising: at least one photon source; at least one controllable photon distributor; a controller connected to the photon source and the photon distributor and programmed to selectively activate at least one of the at least one photon source and to control the controllable photon distributor to expose at least one of the at least one photon-sensitive layers in a selected pattern across the surface thereby selectively revealing a selected subset of sub-pixels of the pixel pattern and portions of photon-sensitive layers thereby producing an image composed of the revealed sub-pixels and photon-sensitive layer portions.

[0045] The invention concerns also an apparatus for producing on a medium a first image in a first image area and a second image in a second image area having a substrate with a surface printed with a first print-pixel area and a second print pixel area, the first print-pixel area being composed of colored sub-pixels that absorb and /or reflect visible light in a predetermined wavelength range when exposed to visible light; the second print pixel area being composed of colored fluorescent sub-pixels that emit in a predetermined wavelength range when exposed to UV light; and having at least one photon-sensitive layer covering the first and the second print-pixel areas and wherein each photon- sensitive layer is in one of a plurality of states wherein each photon-sensitive layer is alterable at selected locations from one of two states to another state of two states, the apparatus comprising: at least one photon source; at least one controllable photon distributor; a controller connected to the photon source and the photon distributor and programmed to selectively activate at least one of the at least one photon source and to control the controllable photon distributor to expose at least one of the at least one photon-sensitive layers in a selected pattern across the surface thereby selectively revealing a selected subset of sub-pixels of the first and the second pixel pattern and portions of photon-sensitive layers thereby producing an image composed of the revealed sub-pixels and photon-sensitive layer portions.

[0046] According to one aspect, the controllable photon distributor is an array of micro-mirrors operable to selectively reflect photons emitted by the photon source onto the medium.

[0047] The controllable photon distributor may be a mask formed by an array of controllable elements that may be altered between an opaque state and a transparent state wherein each controllable element corresponds to a sub-pixel in the print-pixel pattern or a portion of a sub-pixel in the fluorescent print-pixel pattern.

[0048] The controllable photon distributor is for example a position-controllable laser operable to selectively expose areas of the medium corresponding to selected sub-pixels or portions of sub- pixels.

[0049] The apparatus for producing an image may further comprise a heat source for exposing the medium to heat thereby fixing the state of each photon-sensitive layer.

[0050] According to a further aspect, the apparatus for producing an image of comprises a UV source for exposing the medium to UV light thereby fixing the state of each photon-sensitive layer.

[0051] The apparatus for producing an image may comprise a picture taking apparatus connected to say controller and programmed for alignment of the controllable photon distributor with respect to said medium.

[0052] According to one aspect, said medium comprises alignment marks.

[0053] Said medium alignment marks may be disposed on fluorescent print-pixel pattern.

[0054] Alternatively, said medium alignment marks may be disposed on a border portion of said medium that is cut after having produced the colored fluorescent image.

BRIEF DESCRIPTION OF THE DRAWINGS

[0055]

Figure 1 is an exploded perspective view of a prior art identity card that allows some level of personalization of the physical appearance of the card post-issuance.

Figure 2 is a top-view of an identity card according to one embodiment of the technology described herein.

Figures 3(a) and 3(b) are cross-section views of two alternative embodiments of the identity card illustrated in Figure 2.

Figure 4 illustrates the chemical reaction relied upon in one embodiment for the purpose of altering specific locations of one layer of the card depicted in Figures 2 and 3 from transparent to opaque.

Figure 5 is an illustration of one embodiment of a fluorescent print-pixel grid.

Figure 6 is an illustration of an alternative embodiment of a fluorescent print-pixel grid.

Figure 7 is an example photographic image presented for illustrative purposes.

Figures 8a and 8b represent a magnification of a portion of the photographic image of Figure 7 and an even greater magnification of one fluorescent print-pixel used to render one pixel of the image of Figure 7.

Figure 9(a) and (b) are illustrations showing how the various layers set forth in Figure 3 may be manipulated to produce particular colors for one print-pixel.

Figure 10 is a flow chart illustrating the process for producing masks that may be used to control personalization equipment to produce an image on an identity card illustrated in Figures 2 and 3 having a fluorescent print-pixel grid and photon-sensitive layers.

Figure 11 is a flow-chart illustrating a process of using the masks produced from the process from Figure 10 to create an actual image on an identity card.

Figure 12 is a first embodiment of personalization equipment that may be used to produce an image on an identity card.

Figure 13 is a second embodiment of personalization equipment that may be used to produce an image on an identity card.

Figure 14 is a flow-chart of the identity card life cycle modified to personalize identity cards of Figures 2 and 3 in the manner of processes of Figures 9 through 11 using equipment of Figures 12 or 13 or the like.

[0056] In the appended figures, similar components and/or features may have the same reference label. Further, various components of the same type may be distinguished by following the reference label by a dash and a second label that distinguishes among the similar components or by appending the reference label with a letter or a prime (') or double-prime ("). If only the first reference label is used in the specification, the description is applicable to any one of the similar components having the same first reference label irrespective of the second reference label appended letter, or prime.

DETAILED DESCRIPTION OF THE INVENTION

[0057] In the following detailed description, reference is made to the accompanying drawings that show, by way of illustration, specific embodiments in which the invention may be practiced. These embodiments are described in sufficient detail to enable those skilled in the art to practice the invention. It is to be understood that the various embodiments of the invention, although different, are not necessarily mutually exclusive. For example, a particular feature, structure, or characteristic described herein in connection with one embodiment may be implemented within other embodiments without departing from the spirit and scope of the invention. In addition, it is to be understood that the location or arrangement of individual elements within each disclosed embodiment may be modified without departing from the spirit and scope of the invention. The following detailed description is, therefore, not to be taken in a limiting sense, and the scope of the present invention is defined only by the appended claims, appropriately interpreted, along with the full range of equivalents to which the claims are entitled. In the drawings, like numerals refer to the same or similar functionality throughout the several views.

[0058] An embodiment of the invention, provides a mechanism by which physical media such as identification cards, bank cards, smart cards, passports, value papers, etc. may be personalized in a post-manufacturing environment. This technology may be used to place images onto such articles inside a lamination layer after the lamination layer has been applied. In an alternative embodiment, a protective lamination layer is added to the identity card after personalization. Thus, the articles, for example, smart cards, may be manufactured in a mass produced fashion in a factory setting and personalized on relatively inexpensive and simple equipment at a customer location. The technology provides a mechanism for thus personalizing articles, such as smart cards, bank cards, identity cards, with an image that is tamper resistant. Herein, the purpose of providing a clear narrative, the term identity card is used to refer to the entire class of physical media to which the herein-described techniques may be applied even if some such physical media are not "cards" in a strict sense. Without limiting the application of the term identify card it is intended to include all such alternatives including but not limited to smart cards (both contact and contactless smart cards), driver's licenses, passports, government issued identity cards, bankcards, employee identification cards, security documents, personal value papers such as registrations, proofs of ownership, etc.

[0059] In a typical smart card lifecycle, a card is initially manufactured in a factory setting. The manufacturing step includes placing an integrated circuit module and connectors onto a plastic substrate, typically in the shape of a credit card. The integrated circuit module may include systems programs and certain standard applications. The card may also be imprinted with some graphics, e.g., the customer's logo.

[0060] Next the card is delivered to the customer.

[0061] The customer, for example, a government agency, a corporation, or a financial institution, who wishes to issue secure identification cards to its customers, the end-users of the cards, next personalizes the cards. Personalization includes the customer placing its application programs onto the card, and end-user specific information on the card. Personalization may also include personalizing the physical appearance of the card for each end-user, e.g., by printing a name or photograph on the card.

[0062] Once the card has been personalized, the card is issued to the end-user, e.g., an employee or a client of the customer.

[0063] Other identity cards have similar life cycles.

[0064] Figure 1 is an exploded perspective view of a prior art identity card 50 that allows some level of personalization of the physical appearance of the card post-issuance, e.g., by the customer. Such a card 50 may, for example, have the following layers:

- a transparent polycarbonate (PC) layer 59
- a laser-engravable transparent PC layer 57
- an opaque white PC core 5 5

- a laser-engravable transparent PC layer 53

- a transparent PC layer 51

[0065] As anti-counterfeiting measures, the top PC layer 59 may include some embossing 67 and a changeable laser image/multi laser image (CLI/MLI) 69. To further enhance security the card 50 may include features such as a DOVID 65, i.e., a Diffractive Optical Variable Image Device such as a hologram, kinegram or other secure image, and a Sealy's Window 63 (a security feature, provided by Gemalto S.A., Meudon, France, in which a clear window that turns opaque upon tampering is provided in the card). The card 50 may also contain a contact less chip and antenna system 61.

[0066] During personalization the laser-engravable transparent layers 57 and 53 maybe provided with a gray-scale image and identifying text.

[0067] Figure 2 is a top- view of an identity card 100 according to one embodiment of the technology described herein. Briefly, the identity card 100 is provided with a first image area 205 and at least a second image area 206 that are constructed from several layers of material located between a substrate (e.g., a PC core) and a lamination layer.

[0068] The first image area 205 is for example realized according to the description in US 8 314 828 incorporated by reference. The produced image appears as a colored image under visible light exposure.

[0069] As will be best understood from the beneath description, the second image area 206 is a fluorescent image area which differs from the first image area 205 in the sense that under visible light exposure the image appears to be a gray scaled image whereas under UV light exposure, the image exhibits similar coloration as the first image area 205.

[0070] Thus image area 206 allows not only to check the integrity or authenticity of the identity card 100, but also to check the identity of the person to be controlled. Furthermore, the presence of such a gray scaled image area 206 under visible light is a hint for the personal to use UV light exposure to expand the check.

[0071] The bottom layer of these image-area layers are print-pixel grids (see Figures 3 through 8) which consists of a plurality of specifically arranged areas having distinct colors.

[0072] For image area 205, the print pixel grid is realized with inks (for example red, green and blue) working on the reflection or absorption principle in the visible light range.

[0073] This means when visible light impinges such inks, then a certain wavelength is absorbed or reflected in order that a color appears to an observer.

[0074] For image area 206, the print pixel grid is a fluorescent print pixel grid and realized with fluorescent inks (for example fluorescent red, green and blue).

[0075] This means when visible light impinges such inks, the observer does not detect any color information.

[0076] However, when UV light impinges such inks, the UV is absorbed and then reemitted as visible light detectable by the observer.

[0077] In the following, the print pixel grid of image area 205 is designated as the "visible print pixel grid" whereas the print pixel grid of image area 206 is designated as the "fluorescent print pixel grid".

[0078] The realization of the visible print pixel grid is described in US 8314828 and will not be detailed hereafter.

[0079] The visible and the fluorescent print- pixel grids are covered by a transparent layer and an opaque layer of photon-sensitive materials. The transparent layer may be selectively altered to some level of opaque black and the opaque layer may be selectively altered to transparent. Thus, by selective manipulation of the photon-sensitive layers, any given location of the image area 205 or 206 may be made to display a specific color from the print-pixel grid, black (or a darkened shade of the underlying grid sub-sub-pixel), or white. By selectively manipulating the photon- sensitive layers of the addressable locations (as is discussed herein below, the addressable locations are referred to herein as sub-sub-pixels) of the image area, an image may be produced.

[0080] In an alternative embodiment, the fluorescent print-pixel grids are covered only by a transparent-to-opaque layer of photon-sensitive materials. The transparent-to-opaque layer may be selectively altered to some level of opaque black. Thus, by selective manipulation of the photon-sensitive layers, any given location of the image area 205 or 206 may be made to display a specific color from the print-pixel grid and/or black (or a darkened shade of the underlying grid sub-sub-pixel). In this case fluorescent colors may combine additively, for example fluorescent red, green and blue to white. By selectively manipulating the photon-sensitive transparent-to- opaque layer of the addressable locations (as is discussed herein below, the addressable locations are referred to herein as sub-sub-pixels) of the image area, an image may be produced.

[0081] The structure of the print-pixel grid and the photon-sensitive layers, and the process of manipulating these layers to produce an image are discussed in greater detail herein below.

[0082] The identity card 100 may have been printed with a company-logo or other graphic. Through a unique process and manufacture described in greater detail herein below, the identity card 100 contains at least a visible first color image 203, for example, a photograph of the intended end-user, printed in a first image area 205 and at least a second fluorescent second color image 204 under exposure of UV light, for example, a photograph of the intended end-user, printed respectively in said first image area 205 and said second image area 206. According to one aspect, both images 203, 204 are realized on the basis of the same original photography. The identity card 100 may further have been personalized with a printed name 207. The printed name 207 may be applied to the card using the same techniques as described-herein for applying an image 203 to the identity card 100.

[0083] Figure 3(a) is a cross-section of the identity card 100 of Figure 2 taken along the line a-a. The identity card 100 consists of a substrate 107. The substrate 107 may be constructed from a plastic material, for example, selected from polycarbonate polyvinyl chloride (PVC), acrylonitrile butadiene styrene (ABS), PVC in combination with ABS, polyethylene terephthalate (PET), PETG, and polycarbonate (PC). As with the prior art identity card 50 of Figure 1, the identity card 100 may include additional layers, e.g., laser-engravable PC layers 53 and 59 and transparent PC layers 51 and 59.

[0084] A visible print-pixel grid 111 and a fluorescent print pixel grid 112 are located on one surface of the substrate 107 (substrate 107 is meant herein to refer to any of the internal layers of the card 100, e.g., similar to the opaque PC layer 55, either transparent PC layer 53 or 57, or internal layers constructed from alternative materials) in an area of the substrate corresponding to respectively the image areas 205 and 206. The print-pixel grid 112, which is described in greater detail herein below in conjunction with, for example, Figures 4 through 8, may be printed onto the substrate using conventional offset printing or using any other technique for accurately laying down a colored pattern onto the substrate.

[0085] The visible print-pixel grid 111 and the fluorescent print pixel grid 112 are covered by a transparent photon-sensitive layer 105. The transparent photon-sensitive layer 105 is manufactured from a material that converts from being transparent to some level of opaqueness upon being exposed to photons of particular wavelength and intensity. Suitable materials include carbon- doped polycarbonate. Traditionally polycarbonate (PC) ID products have been personalized using laser-engraving technology. This personalization is based on a laser beam heating carbon particles inside specific polycarbonate layers to the extent that the polycarbonate around the particle turns black. While the particles could be materials other than carbon, it is the intrinsic property of polycarbonate that creates the desired contrast and number of gray levels to allow creation of a photographic image. The gray tone is controlled by the laser power and speed of scanning across the image areas 205 and 206. Thus, a carbon-doped transparent PC layer may be selectively altered into an opaque layer along the darkness scale by exposing select location with a Nd-YAG laser or Fiber Laser. A Nd-YAG laser emits light at a wavelength of 1064 nanometers in the infrared light spectrum. Other Nd-YAG laser wavelengths available include 940, 1120, 1320, and 1440 nanometers. These wavelengths are all suitable for turning a transparent PC layer opaque black or partially opaque with an intensity in the range of 10 to 50 watts. In a typical application, the Nd-YAG laser is scanned (in the manner discussed in greater detail below) over the image area for a duration of approximately 4 seconds exposing specific locations as required. Fiber lasers that are suitable for turning the transparent PC layer opaque or partially opaque operate in wavelengths in the range of 600 to 2100 nanometers. While some specific lasers and wavelengths are discussed herein above, any alternative photon source, e.g., a UV laser, that converts a location on a transparent PC layer opaque may be employed in lieu thereof.

[0086] The transparent photon-sensitive layer 105 is covered with an opaque layer 103 that may be altered into a transparent layer by exposure to photons in a particular wavelength and intensity. Suitable materials for the opaque-to - transparent photon- sensitive layer include a white bleachable ink that may be laid down on top of the transparent-to-opaque layer 105 through thermal transfer or dye sublimation, for example. Examples, include SICURA CARD 110 N WA (71-010159-3-1 180) from Siegwerk Druckfarben AG, Sieburg, Germany, Dye Diffusion Thermal Transfer (D2T2) inks available from Datacard Group of Minnetonka, Minnesota, USA or Dai Nippon Printing Co., Tokyo, Japan. Such materials may be altered selectively by exposing particular locations by a UV laser at a wavelength of, for example, 355 nanometers or 532 nanometers with an intensity in the range of 10 to 50 watts for a few milliseconds per addressable location (sub-sub- pixel). To alter the sub-sub-pixels in the opaque-to-transparent layer 103 the laser is continuously scanned over the image area exposing those sub-sub-pixels that are to be altered from opaque white to transparent in the opaque-to-transparent layer 103 by ink bleaching or evaporation. In an alternative embodiment, the same UV laser wavelength that removes the ink of the opaque-to-transparent layer 103 may also be used to alter the carbon-doped transparent-to-opaque layer 105 below the removed sub-sub-pixels of the opaque-to-transparent layer 103 when there is residual power available from the UV laser.

[0087] In an alternative embodiment the opaque-to-transparent layer 103 is a photon-sensitive layer that is amenable to a dry photographic process that requires no chemical picture treatment. One example is spiropyran photochrom with titanium oxide (similar to the material used to produce with PVC). This process is based on the photochemical behavior of colored complexes between spiropyrans and metal ions. Figure 4 illustrates the chemical reaction. When spiropyran SP2 401, which is a closed structure, is exposed to UV light, it transforms into an open structure 403 that is colored. A suitable alternative to SP2 401 is spiropyran indolinic (3'3'-dimethyl- 1-isopropyl-8-methoxy-6-nitrospiro[2H-1-benzopyrane-2,2-indoline]).

[0088] In an alternative embodiment, illustrated in Figure 3(b), the opaque-to-transparent layer 103 is augmented with a doped organic semiconductor layer 106. The doped organic semiconductor layer 106 is useful as an amplifier to improve the speed by which the opaque-to-transparent layer 103 transforms from opaque to transparent. Example materials for the doped organic semiconductor layer 106 include polyvinyl carbazol and polythiophenes. A polyvinyl carabazol layer 106 may be laid down by evaporation of 2.5 grams of polyvinyl carabazol in 50 cubic- centimeters of dichloromethane. The semiconductor layer 106 is preferably doped to match the energy levels required for a photochromic effect in the opaque-to-transparent layer 103.

[0089] The photochromic effect of spiropyran-based opaque-to-transparent layer 103 may be achieved by exposure to visible or ultraviolet light. The preferred intensity is in the range of 50 to 200 watts at a distance of 30 to 300 millimeters for a duration of 10 to 300 seconds.

[0090] The principle of preparation of emulsions for a dry color printing process has been patented by Prof. Robillard (US Pat. Appl. 2004259975). The result of feasibility investigation is described in a J. Robillard et al, Optical Materials, 2003, vol. 24, pp 491-495. The process involves photographic emulsions that require exclusively light of the UV or visible range for producing and fixing images. The emulsions include colored photochromic dyes and a system for amplification and exhibit photosensitivity comparable to those of the known silver-containing conventional materials. In general, this process is applicable for any kind of supports (paper, tissues, polymeric films).

[0091] Finally, the identity card 100 is covered with an upper lamination layer 109a and a lower lamination layer 109b. The lamination layers 109 provide security in that they protect the images 203 and 204 produced respectively in the image areas 205 and 206 from physical manipulation. The upper lamination layer 109a should be transparent to the photon wavelengths used for altering the transparent-to-opaque layer 105 and the opaque-to-transparent layer 103. Furthermore, the lamination temperature should be low enough as to not alter the transparent-to-opaque layer 105 or opaque-to-transparent layer 103, for example, in the range of 125 to 180 degrees Celsius. Suitable materials include PVC, PVC-ABS, PET, PETG, and PC.

[0092] While it is desirable to prepare the entire card during the manufacturing phase of the card life-cycle, in some embodiments applying the technology described herein that is not practical because the upper lamination layer 109a could prevent evaporation of dyes from the opaque-to-transparent layer 103 or 111". Therefore, if the alteration of one of the photon-sensitive layers requires evaporation or some other form of material removal in the process of transforming from one state to another, e.g., from opaque to transparent, the upper lamination layer 109a may be added during the personalization phase, for example, after the image areas 205 and 206 have been personalized as described herein. Such lamination may be performed using DNP CL-500D lamination media from Dai Nippon Printing Co., Tokyo, Japan or other suitable lamination technology.

[0093] Turning now to the structure of the fluorescent print-pixel grid 112, for which a small portion is illustrated in Figure 5. The fluorescent print-pixel grid 112 is composed of an array of print-pixels 501. A print-pixel 501 corresponds to a pixel in a bitmap of an image, e.g., one pixel in a file in the .bmp format. In the small portion of a fluorescent print-pixel grid 112 illustrated in Figure 5, contains a 4 x 7 grid of print-pixels 501. In a real-life fluorescent print-pixel grid 112, a grid having many more print-pixels in each dimension would be necessary for producing a meaningful image. Each print-pixel 501 contains 3 rectangular sub-pixels 503a, 503b, and 503c, each corresponding to a unique fluorescent color, e.g., fluorescent green, fluorescent blue, and fluorescent red as illustrated in the example. The fluorescent colors are formed by specific fluorescent inks that under visible light do not reflect or absorb in a specific wavelength range. This means that under visible light conditions (for example day light) the fluorescent colors appear to be transparent as they do not reflect or absorb a specific color. However, under UV light, light emission is stimulated in the fluorescent inks and each fluorescent color emits light in the visible spectrum in a specific wavelength range, for example green, blue or red. For the purpose of being able to produce various color combinations, each sub-pixel 503 is subdivided into a plurality of sub-sub-pixels 505. In the example of Figure 5, each sub-pixel 503 is composed of a 2 x 6 grid of sub-sub-pixels 505.

[0094] The term "print-pixel" is used herein to the equivalent of a pixel in a digital image that is printed in the fluorescent print-pixel grid and having a plurality of sub-pixels that each form a portion of the print-pixel, and the corresponding areas in the photon- sensitive layers that cover the image area 205. A sub-pixel is a fluorescent single-color area of the fluorescent print-pixel. A sub-sub-pixel is a single addressable location in a sub-pixel. Thus, a sub-pixel is composed of one or more sub-sub-pixels. A sub-sub-pixel may take its exposed fluorescent color from either the print-pixel grid or any of the photon-sensitive layers.

[0095] Figure 6 is an illustration of an alternative fluorescent print-pixel grid 112" composed of print-pixels 501" that are composed of hexagonal sub-pixels 503". As is illustrated in Figure 6(b), each hexagonal sub-pixel 503" is composed of six triangular sub-sub-pixels 505" that when connected form the hexagonal sub-pixel 503". As must be appreciated, while Figures 5 and 6 illustrate two different fluorescent print-pixel structures, there are many more possible structures. All such alternatives must be considered equivalents to the print-pixel structures illustrated here as examples.

[0096] Figure 7 is a color photograph 701 of a model and is presented here as an illustrative example. Consider the lower-left quarter 703 of the model's right eye (right and left being from the perspective of the viewer). This portion 703 of the model's eye is shown in greater magnification in Figure 8. The image 701 is created by selectively turning on specific colors from the transparent-to-opaque layer 105, the opaque-to-transparent layer 103, and from the print-pixel grid 112 for each sub-sub- pixel 505 that make up the print-pixels 501 forming the image. Consider the lower left print-pixel 501" of the eye portion 703. The lower left print-pixel 501" lies on the model's lower eyelid and has pinkish red fluorescent coloration. To achieve that coloration, a large portion of the fluorescent red sub-pixel 503c" is revealed by 8 of 12 fluorescent red sub-sub-pixels 505 of the underlying print-pixel grid. The fluorescent blue sub-sub-pixels are entirely obscured by the opaque white layer and most of the fluorescent green sub-sub-pixels are obscured by the black layer, thereby giving a neutral brightness and primarily fluorescent red coloration to the print- pixel 501".

[0097] Figure 9(a) illustrates the manipulation of the opaque-to-transparent layer 103 and the transparent-to-opaque layer 105 to produce desired fluorescent colors for a fluorescent print-pixel 501 by displaying the cross-section of each of a black print-pixel 501a, a white print-pixel 501b, a fluorescent red print-pixel 501c, and a fluorescent blue print-pixel 501d. For each print-pixel 501a through 501d illustrated in Figure 9(a), each column represents one sub-pixel 503. Sub-sub-pixels 505 are not illustrated in Figure 9(a). To produce a solid black print-pixel 501a, the opaque-to-transparent layer 103 is made transparent (T) by exposing the print-pixel 501a to the state-changing light necessary to alter the opaque-to-transparent layer 103 of the print-pixel from opaque white (W) to transparent (T). To produce a solid white print-pixel 501b the print-pixel 501b is not illuminated at all because the default state for die opaque-to-transparent layer 103 is white. For a solid white print-pixel 501b, the transparent-to-opaque layer 105 may have any value as it is occluded by the opaque white layer 103. However, typically it would be left transparent (T). To produce a red fluorescent print-pixel 501c, both the opaque-to-transparent layer 103 and the transparent-to-opaque layer 105 are configured in their transparent state (T) for the area over the red (R) sub-pixel. That effect is produced by exposing the opaque-to-transparent layer 103 to the state-altering photons for the opaque-to-transparent layer 103 while leaving the transparent-to-opaque layer 105 in its native state. The opaque-to-transparent layer 103 for either the fluorescent green or fluorescent blue sub-pixel may be altered to transparent (T) and the corresponding location on the transparent-to-opaque layer 105 may be altered to black (K) to reveal a black sub-pixel. By combining black and white sub-pixels or sub-sub-pixels for the non-colored sub- pixels or sub-sub-pixels may be used to adjust the brightness of the pixel 501. In case of fluorescent ink and colors, this is of particular importance in order to prevent a "glow" effect and the problem of blurred image details that would lead to difficulties for identification of the document. The blue fluorescent pixel 50 Id is produced similarly to the red fluorescent pixel 501c.

[0098] Figure 9(b) illustrates an alternative embodiment to that illustrated in figure 9(a) with only one photo sensitive layer and taking the advantage that due to fluorescence of the pixels, colors may also be obtained through additive color composition, in particular additive RGB color composition.

[0099] In this case, the photo sensitive layer may in particular be a transparent-to-opaque layer 105 (transparent (T) to black (K)) to produce desired fluorescent colors for a fluorescent print-pixel 501 by displaying the cross-section of each of a black print-pixel 501'a, a fluorescent white print-pixel 501'b, a fluorescent red print-pixel 501'c, a fluorescent blue print-pixel 501'd, a fluorescent green print-pixel 501'e, and a fluorescent yellow print-pixel 501'f.

[0100] For each print-pixel 501'a through 501'f illustrated in Figure 9(b), each column represents one sub-pixel 503. Sub-sub-pixels 505 are not illustrated in Figure 9(b). To produce a solid black print-pixel 501'a, the transparent-to-opaque layer 105 is made opaque (K) by exposing the print-pixel 501'a to the state-changing light necessary to alter the transparent-to-opaque layer 105 of the print-pixel from transparent to black (K). To produce a solid white print-pixel 501'b, the print-pixel 501'b is not illuminated at all and left in its native state because the default state for die transparent-to-opaque layer 105 is transparent. Then, under exposure to UV light, red, green and blue sub-sub-pixel 505 will emit their respective fluorescent colors which would appear white to an observer.

[0101] To produce a red fluorescent print-pixel 501'c, the transparent-to-opaque layer 105 is configured in its transparent state (T) for the area over the red (R) sub-pixel and left native opaque over the green (G) sub-pixel and the blue (B) sub-pixel. To produce a blue fluorescent print-pixel 501'd, the transparent-to-opaque layer 105 is configured in its transparent state (T) for the area over the blue (B) sub-pixel and left native opaque over the green (G) sub-pixel and the red (R) sub-pixel. To produce a green fluorescent print-pixel 501'e, the transparent-to-opaque layer 105 is configured in its transparent state (T) for the area over the green (G) sub-pixel and left native opaque over the red (R) sub-pixel and the blue (B) sub-pixel. To produce a yellow fluorescent print-pixel 501'f, the transparent-to-opaque layer 105 is configured in its transparent state (T) for the area over the red (R) sub-pixel the green (G) sub-pixel, and left native opaque over the blue (B) sub-pixel. In a similar way by additive color combination, cyan may be obtained by combining blue and green fluorescent sub-sub-pixels and magenta may be obtained by combining blue and red fluorescent sub-sub-pixels.

[0102] By combining in addition with black sub-pixels or sub-sub-pixels the brightness of the pixel 501 may be adjusted. In case of fluorescent ink and colors, this is of particular importance in order to prevent a "glow" effect and the problem of blurred image details that would lead to difficulties for identification of the document.

[0103] While Figure 9(a) and 9(b) illustrate the manipulation of the photon-sensitive layers on a sub-pixel level, it must be noted that actual fluorescent print-pixels 501 are composed of many fluorescent sub-sub-pixels 505 and that many color and brightness variations may be produced by selectively revealing colored fluorescent, black, and white (when present) sub-sub-pixels in suitable combination to produce the desired fluorescent coloration and brightness for a given print-pixel 501.

[0104] In addition, the ink being fluorescent the white is not essential for the fluorescent color image, in particular when the light is only UV light. But the use of the blackmask and white mask can also be used for optimizing the black and white effect on the photo under normal light. The man of the art will understand that even if only one mask is sufficient, the use of two mask have additional interest for a security feature for preventing forgery.

[0105] Now it is turned to the computation of masks for the transparent-to-opaque layer 105 and the opaque-to-transparent layer 103. The determination of which sub-sub-pixels 505 are to be left opaque white, are to be turned into opaque black, or are to reveal the underlying fluorescent color from the print-pixel grid 112 is controlled by a mask for each of the photon-sensitive layers. These masks may, for example, have an on/off value for each sub-sub-pixel in the image area 205 or a value indicate the level of opacity the particular photon-sensitive layer is to provide for each sub-sub-pixel. Figure 10 is a flowchart illustrating the steps of one embodiment for computing these masks. The description should not be considered limiting as there are other possible algorithms for producing the masks.

[0106] The process 110 accepts as input a digital image 121, for example, in the .bmp format. A .bmp format image file 121 is a bitmap for each pixel in an image to particular RGB (red-green-blue) values. The process 110 converts the image file 121 into an exposure mask white 125a and an exposure mask black 125b. These exposure masks 125 are provided as input to a controller 355 (Figures 12 and 13) for controlling the exposure of sub-sub-pixels of the transparent-to-opaque layer 105 and opaque-to-transparent layer 103, The goal in designing the masks 125 is to produce an image that resembles the image of the digital image file 121.

[0107] It is assumed here that there is a one-to-one correspondence between each pixel of the source image 121 to each print-pixel 501 of the fluorescent print-pixel grid 112. Otherwise, a pre-processing conversion algorithm can be applied. Furthermore, the process 110 is described with respect to square print-pixels 501 with three rectangular sub-pixels 503 for fluorescent green, fluorescent blue and fluorescent red, respectively, as illustrated in Figure 5. In alternative embodiments, other pixel and sub-pixel shapes and fluorescent colors are possible. For example, in one alternative, the print-pixel pattern includes either black or white (or both) sub-pixels that may take the place of one of the photon-sensitive layers 103 or 105. In yet another alternative, the fluorescent print-pixel pattern includes colors such as cyan, magenta, and yellow to allow for greater variability in displayed colors. For such alternatives, the process 110 would be modified to account for such different structures in the fluorescent print-pixel pattern and the covering photon-sensitive layers.

[0108] From one perspective an objective of the process 110 is to determine how much of each color sub-pixel 503 is to be visible for each fluorescent print-pixel in the resulting image 204 when exposed to UV light. A second objective is the determination of the opacity for the transparent-to-opaque layer 105 because that layer may take on varying degrees of opacity. Third, the process 110 determines the ratio between black and white fully obscuring sub- sub-pixels and the locations for such sub-sub-pixels.

[0109] The brightness of each source pixel is determined, step 127.

[0110] Next white level adjusted RGB values are computed in step 129.

[0111] Next a hue enhancement is computed and the adjusted RGB values are further adjusted for the hue enhancement, step 131.

[0112] Next, each print-pixel is brightness adjusted in step 133.

[0113] Step 133, thus, computes the overall portion of each print-pixel 501 that should be fully opaque black to be used in computations described herein below. This allows preventing any glow effect or blurring.

[0114] The number of revealed fluorescent sub-sub-pixels for each fluorescent color and also the number of sub-sub-pixels for black cover are both victim of quantization error during the computations. For the herein-described case of twelve sub-sub-pixels per sub-pixel, this quantization error does not have an easily perceptible effect on the image for a human viewer, and the quantization errors can be ignored. If a fluorescent print-pixel is designed with fewer sub-sub-pixels per sub-pixel, then these quantization errors become more noticeable in the produced image quality. The human eye is much more sensitive to brightness errors than color errors, so the priority is to repair the brightness quantization errors. The adjustability of the transparent-to-black photosensitive layer 105 allows an opportunity for correction.

[0115] At this point, one knows how many of each sub-sub -pixels 505 to reveal for each sub-pixel 503, and how many sub-sub-pixels to render black.

[0116] Next the sub-sub-pixels that are to be opaque (white or black) are mapped on the grid of sub-sub-pixels 505 that make up the print-pixel 501, step 135. A preference is given to have opacity located on the periphery of the print-pixel 501. This result is achieved by ordering the sub-sub-pixels as to their relative order of priority for being made an opaque sub-sub-pixel. The opaque sub - sub-pixels are located according to that priority ordering until all opaque sub-sub-pixels have been assigned particular locations. If assigning opacity to a particular sub-sub-pixel would render the sub-pixel to which that sub-sub-pixel belong as having too few revealed sub-pixels from the fluorescent print-pixel grid layer 112, the opacity is assigned to the next fluorescent sub-sub-pixel in the opacity preference order.

[0117] At this point the opacity map 123 has been computed.

[0118] Next, the black cover map is computed. That calculation commences with determining the brightness positioning preference, step 137. To achieve sharp representation of brightness boundaries, the source image 121 is analyzed to identify sharp brightness boundaries and to set up a brightness positioning preference for each fluorescent print-pixel 501; for fluorescent print-pixels that do not lie on a brightness boundary, no brightness positioning preference is assigned.

[0119] For each pixel in the source image 121 direction and magnitude of the greatest brightness contrast is identified by comparing adjacent pixels while ignoring the brightness of the pixel for which a brightness positioning preference is being determined.

[0120] Next a darkness ordering preference is computed, Step 139.

[0121] Next the opaque black sub-pixels are allocated to the sub-sub-pixels that make up the fluorescent print-pixel, step 141. Each black opaque sub-sub-pixel is allocated to a sub-sub-pixel in the order provided by the darkness ordered list of sub-sub-pixels. If as a black opaque pixel is to be allocated has not been marked to be opaque in the opacity map 123, that sub-sub-pixel is not marked as black and the next sub-sub-pixel in the darkness ordered list of sub-sub-pixels is considered. If the sub-sub-pixel has been marked to be opaque in the opacity map 123, it is marked to be black.

[0122] At the conclusion of this, the process 110 has determined the location of white sub-sub-pixels for the opaque-to-transparent layer 103 and black sub-sub-pixels revealed from the transparent-to- opaque layer 105. Next these maps are translated in to exposure patterns for each of the photon sensitive layers 103 and 105, step 143, resulting in an exposure mask for white 125a corresponding to the opaque -white-to- transparent layer, and an exposure mask for black 12 5b corresponding to the transparent-to-black layer.

[0123] Figure 11 is a flow-chart illustrating a process 150 of using the masks produced from the process 110 to create an actual image on an identity card 100.

[0124] First, the identity card 100 and the exposure equipment are aligned to assure accurate exposure of the photon sensitive layers 103 and 105 to produce the image, step 151. In particular the alignment needs to be realized with respect to the fluorescent print pixel grid 112. Indeed misalignment could result in revealing the incorrect sub-sub-pixels from the print- pixel array 112. Thus, accurate alignment is very important.

[0125] In case of use of fluorescent inks (fluorescent red, green or blue for example) for the fluorescent print pixel grid layer 112, this alignment is even more harsh as under visible light, one cannot detect the different fluorescent colors in the grid.

[0126] The alignment can be achieved in using specific alignment marks on the card 100 or on the print pixel grid 112. As an example, such an alignment mark can be disposed in a peripheral area of the card 100, or in a peripheral area of the print pixel grid 112, such as a corner. In an alternative, such alignment marks may be disposed on a border portion of the card 100 that is cut after having produced the colored fluorescent image.

[0127] Next, the white layer mask 125a is used to turn-off masking of sub-sub-pixels in the opaque-to-transparent layer 103 that are to be converted from opaque white to transparent, step 153.

[0128] The image area is then exposed to photons in the correct wavelength and intensity to convert from opaque to transparent, step 155.

[0129] Next, the transparent-to-opaque layer 105 is converted from transparent to black by first unmasking the sub-sub-pixels that are to be converted to black, step 157.

[0130] The unmasked sub-sub-pixels are next exposed to the requisite photons to cause the conversion from transparent to black, step 159.

[0131] Finally, the image is fixed through a fixation step 161. The method by which the image is fixed, i.e., the method by which the opaque-to -transparent layer 103 and transparent-to-opaque layer 105 are prevented from changing to other states, varies by material. The most straightforward case is for the opaque-to-transparent layer 103 being bleachable ink. Certain bleachable inks have been found to evaporate when exposed to UV laser. Thus, when the opaque-to-transparent layer 103 is transformed from opaque to transparent by removal of the pigmentation from that layer, it is not possible to revert back to being opaque. It is a one-way transformation.

[0132] If the opaque-to-transparent layer 103 is a spiropyran layer, the layer may be made fixable by including a fixing material in the layer, e.g., Ludopal as a photoreticulable polymer with benzoyl peroxide as radical initiator. This layer 103 may be fixed through exposure to UV light in the range of 488nm to 564nm with a power of approximately 3.5 milliwatts/cm^2 for approximately 5 seconds. Suitable equipment includes a black ray lamp B-100 A, No 6283K-10, 150W from Thomas Scientific of Swedesboro, New Jersey, U.S.A. As an alternative a spiropyran opaque- to-transparent layer 103 may be fixed using heated rolls, e.g., 3M Dry Silver Developer Heated Rolls at 125 degrees Celsius on medium speed.

[0133] As under exposure under UV light, the produced fluorescent color image appears, a final quality check step 163 may be envisaged by taking a picture of the fluorescent image and comparing it to the original one.

[0134] This can be done just on the very last milliseconds of the exposure to UV light in step 161 for fixation and allows enhancing the quality of the personalized identity card 100.

[0135] Attention is now drawn to equipment that may be used for producing an image 204 in an image area 206 of an identity card 100. Figure 12 is a block diagram of a first embodiment of a personalization station 351 for producing an image 204 in the manner described herein above. A .BMP digital image 121 is input into a mask computer 353. The mask computer 353 may be a general-purpose computer programmed to perform the computations of process 110 described herein above in conjunction with Figure 10. The mask computer 353 thus includes a storage medium for storing instructions executable by a processor of the mask computer 353. When the processor loads these instructions, which include instructions to perform the operations of process 110, into its internal memory and executes the instructions with respect to the input .BMP image 121, the mask computer 353 produces the masks 125.

[0136] In case of use of fluorescent inks (fluorescent red, green or blue for example) for the fluorescent print pixel grid layer 112, the alignment is even more harsh as a camera in the visible cannot detect the different fluorescent colors under visible light.

[0137] In order to achieve such an alignment, the apparatus 351 for producing an image further comprises a picture taking apparatus 364 like a camera connected to the controller 355. The controller is programmed to align the controllable photon distributor, for example an array of micro-mirrors 357 with respect the card 100 in using specific alignment marks 366.

[0138] As shown on figure 12, these alignment marks may be disposed on fluorescent print-pixel pattern 112.

[0139] The alignment marks may in an alternative be disposed on a border portion of said card 100 that is cut after having produced the colored fluorescent image, that is after fixation step 161 or quality check step 163.

[0140] The masks 125 are input into a process controller 355. The process controller 355 is programmed to perform the steps of process 150 of Figure 11.

[0141] Thus the process controller 355 may use the masks to control the array of micromirrors 357 such that when a photon beam 359 emitted from a photon point source 361 is directed upon the micromirrors 357 the latter redirects the photon beam solely onto those sub-sub-pixels of the image area 205 that are to be exposed according to the masks 125. The controller 355 may also be programmed to control the photon source 361 to cause appropriate duration exposure of these sub -sub-pixels. In an alternative embodiment uses an array for micro-fresnel lenses in lieu of the micromirrors 357. In such an embodiment, each Fresnel lens provides a focus onto a specific sub-sub-pixel.

[0142] It should be noted that identity card 100 comprises in general, as shown in figure 2, first image area 205 where the produced image appears colored under visible light exposure and second image area 206, for example adjacent to the first image area 205, where the produced image appears gray under visible light exposure and colored under exposure of UV light.

[0143] As appears from the above description, the images of the first image area 205 and the second image area 206 may be produced in parallel during process 150 with the same apparatus 351.

[0144] This is quite advantageously for the customer for the personalization process as he only needs one equipment. The process is not slowed down while adding a supplemental efficient security feature on the card 100.

[0145] Figure 13 is an alternative embodiment of a personalization station 351' for producing an image 203 in an image area 205 of an identity card 100. In the case of the personalization station 35 V, a controller 355' is programmed to accept the masks 125 to control a light array 363 that is composed of a plurality of light sources. The light array 363 produces photons in the appropriate wavelength and intensity to convert the photon-sensitive layers of corresponding locations in the image area 205. In an embodiment, the photon beams produced by the light array 363 are focused through one or more lenses 365 to cause the trajectory of the photon beams onto the appropriate sub-sub-pixel locations in the image area 205.

[0146] Figure 14 is a flow-chart of a smart card life cycle 370 extended to include the technology described herein. In the card- manufacturing step 10, the print-pixel grids 111 and 112 are printed onto a substrate 107 of each card, step 11. This may be, for example, be performed through standard offset printing. Next the transparent-to-opaque layer 105 layer is deposited onto the card, step 13. Next the opaque-to- transparent layer 103 is placed on the card, step 15. And finally the card is laminated, step 17a. It should be noted that in some embodiments of the identity card 100, the lamination step is performed after the image 203 has been produced on the card 100. As well understood by the man of the art, only one of steps 13 and 15 can be perform if only one photosentive layer is used.

[0147] The resulting manufactured card 100 has a first and a second image area 205 and 206 that consist of the print-pixel layers 111 and 112, the transparent-to-opaque layer 105, and the opaque-to- transparent layer 103 all optionally under a laminate layer 109. The cards 100 may now be delivered to customers, step 20.

[0148] At the customers' locations, the cards 100 may be personalized for end-users, step 30. This includes rendering an image of the end-user onto the card, step 31, in the manner described herein above by converting an image file into masks 125 that maybe used to control equipment that expose select locations of the image areas 205 and 206 to photons that selectively reveal or conceal sub-sub-pixels of various specified visible and fluorescent colors. After the image has been created, it is fixed, step 33. Alternatively, the cards 100 may be protected against alteration by adding a filter that filters out photons that would alter the photon-sensitive layers, e.g., by applying a filtering varnish to the card. In yet another alternative, an additional transparent layer is included between the upper lamination layer 109a and the photon-sensitive layers 103 and 105. This additional layer is also a photon sensitive layer. This additional layer, upon being exposed to photon energy or heat, transforms from being transparent to the wavelengths that transform the opaque-to-transparent layer 103 and transparent-to-opaque layer 105 to being opaque to those wavelengths thereby blocking any attempts to alter the image 203.

[0149] As described herein above, in some embodiments the change from opaque to transparent relies on evaporating away ink from the opaque-to-transparent layer 103. Therefore, the personalization phase 30 may conclude with a lamination layer 17b after the personalization of the image areas 205 and 206. The post-person lamination step 17b also provides an alternative opportunity for laying down a filter that blocks photons that could otherwise further alter the image 203, in which case the fixation step 33 and the lamination step 17b may be considered to be one step.

[0150] Finally the card 100 maybe issued to an end-user 40.

[0151] Thus, the smart card life cycle has been successfully modified to provide for post-issuance personalization by placing an end-user image on the card under a laminate thereby improving the personalization of the card while providing for a high degree of tamper resistance and by adding a further security feature with an image that appears gray under visible light exposure and colored under exposure to UV light.

[0152] This not only facilitates the identity check of the person to be controlled but also the verification of the authenticity of the identity card 100.

[0153] From the foregoing it will be apparent that a technology has been presented herein above that allows for personalization of sensitive articles such as identification cards, bank cards, smart cards, passports, value papers, etc. in a post- manufacturing environment. This technology may be used to place images onto such articles inside a lamination layer which may be applied before or after the lamination layer has been applied. Thus, the articles, for example, smart cards, may be manufactured in a mass produced fashion in a factory setting and personalized on relatively inexpensive and simple equipment at a customer location. The technology provides a mechanism for thus personalizing articles, such as smart cards, bank cards, identity cards, with an image that is tamper proof.

[0154] While the above description focuses on smart card personalization, which is a field in which the above described technology is ideally suited, the reliance on smart cards herein should only be considered as an example. The technology is also applicable to other devices and documents that benefit from secure personalization with an image. Some examples include identification cards, banc cards, smart cards, passports, value papers.

[0155] Although specific embodiments of the invention have been described and illustrated, the invention is not to be limited to the specific forms or arrangements of parts so described and illustrated. The invention is limited only by the claims.

Claims

1. A method for producing a colored fluorescent image when exposed to UV light in an image area on a physical media, comprising:

- printing a fluorescent print-pixel pattern on a substrate surface wherein the print-pixel pattern comprises a plurality of fluorescent print-pixels, each fluorescent print-pixel composed of a plurality of differently- colored fluorescent sub-pixels that emit in a predetermined wavelength range when exposed to UV light;
- covering the print-pixel pattern with at least one photon-sensitive layer wherein each photon-sensitive layer is in one of a plurality of states wherein each photon-sensitive layer is alterable at selected locations from one of two states to another state of two states;
- altering the state of at least one of the at least one photon-sensitive layers in a selected pattern across the physical media thereby selectively revealing a selected subset of sub-pixels and portions of photon- sensitive layers corresponding to other sub-pixels thereby producing an image composed of the revealed sub-pixels and photon-sensitive layer portions corresponding to other sub-pixels.

2. A method for producing on a physical media a first image in a first image area and a second image in a second image area, where the first image is a colored image under exposure to visible light and the second image is a gray image under exposure to visible light and a colored image under exposure to UV light, comprising:

- printing a first print-pixel pattern and a second print-pixel pattern on a substrate surface wherein the first print-pixel pattern comprises a plurality of visible print-pixels and the second print-pixel pattern comprises a plurality of fluorescent print-pixels, each visible print-pixel composed of a plurality of differently colored sub-pixels that absorb and/or reflect light in a predetermined wavelength range when exposed to visible light; each fluorescent print-pixel composed of a plurality of differently- colored fluorescent sub-pixels that emit in a predetermined wavelength range when exposed to UV light;
- covering the first and the second print-pixel pattern with at least one photon-sensitive layer wherein each photon-sensitive layer is in one of a plurality of states wherein each photon-sensitive layer is alterable at selected locations from one of two states to another state of two states;

altering the state of at least one of the at least one photon-sensitive layers in a selected pattern across the physical media thereby selectively revealing a selected subset of sub-pixels and portions of photon-sensitive layers corresponding to other sub-pixels thereby producing an image composed of the revealed sub-pixels and photon-sensitive layer portions corresponding to other sub-pixels

3. The method of Claim 1 or 2 wherein a first photon-sensitive layer is visually opaque and transforms into visually transparent upon exposure to photons of a first selected wavelength and intensity; wherein a second photon-sensitive layer is visually transparent and transforms into visually opaque upon exposure to photons of a second selected wavelength and intensity; wherein a first selected portion of the first photon-sensitive layer is exposed to reveal sub-pixels on the surface or any photon-sensitive layers between the print-pixel pattern located on the surface and the first photon-sensitive layer; and wherein a second selected portion of the second photon-sensitive layer is exposed to occlude sub-pixels on the surface and any photon-sensitive layers between the surface the second photon- sensitive layer.

4. The method of Claim 1 or 2 wherein the at least one photon-sensitive layer transforms from opaque white into visually transparent.

5. The method of Claim 1 or 2 wherein the second photon-sensitive layer transforms from visually transparent into opaque black.

6. The method of Claim 4 and 5 wherein, wherein the second photon-sensitive layer is positioned in between the first photon-sensitive layer and the print-pixel pattern located on the substrate surface.

7. The method of Claims 6 comprising revealing a colored fluorescent sub-pixel by exposing an area of the first photon-sensitive layer located above the colored sub-pixel to be revealed to photons of the first wavelength and intensity; and
creating a black sub-pixel at a particular location by revealing an area of the second photon- sensitive layer corresponding to the particular location by exposing an area of the first photon-sensitive layer corresponding to the particular location to photons of the first wavelength and intensity and darkening the area of second photon- sensitive layer corresponding to the particular location by exposing the area of the second photon- sensitive layer also corresponding to the particular location to photons of the second wavelength and intensity.

8. A medium personalizable by selective exposure to photons, comprising:

a fluorescent print-pixel pattern layer having a fluorescent print-pixel pattern comprising a plurality of fluorescent print-pixels, each fluorescent print-pixel composed of a plurality of differently- colored fluorescent sub-pixels that emit in a predetermined wavelength range when exposed to UV light; at least one photon-sensitive layer composed of a photon-sensitive material that transitions from a first state to a second state upon exposure to photons of a first wavelength and intensity.

9. A medium personalizable by selective exposure to photons, comprising:

a print pixel pattern layer having a first the print-pixel pattern and a second print-pixel pattern, the first print-pixel pattern comprising a plurality of visible print-pixels, each visible print-pixel composed of a plurality of differently colored sub-pixels that absorb and /or reflect visible light in a predetermined wavelength range when exposed to visible light; the second print pixel pattern comprising a plurality of fluorescent print-pixels, each fluorescent print-pixel composed of a plurality of differently- colored fluorescent sub-pixels that emit in a predetermined wavelength range when exposed to UV light; at least one photon-sensitive layer composed of a photon-sensitive material that transitions from a first state to a second state upon exposure to photons of a first wavelength and intensity.

10. The medium personalizable by selective exposure to photons of claim 8 or 9, wherein the at least one photon-sensitive material comprises: a transparent layer covering the pixel pattern and composed of a photon-sensitive material that transitions to some level of opaqueness upon being exposed to photons of the first wavelength and intensity.

11. The medium personalizable by selective exposure to photons of claim 8 or 9, wherein the at least one photon-sensitive material comprises: an opaque layer covering the fluorescent pixel pattern and composed of a photon-sensitive material that transitions to being transparent upon being exposed to photons of a second wavelength and intensity.

12. The medium personalizable by selective exposure to photons of claims 10 where the transparent layer is a laser-engravable carbon-doped polycarbonate layer.

13. The medium personalizable by selective exposure to photons of claim 11 where the opaque layer is a bleachable ink.

14. An apparatus for producing an image in an image area on a medium having a substrate with a surface printed with a fluorescent print-pixel pattern when exposed to UV light and having at least one photon-sensitive layer covering the fluorescent print-pixel pattern and wherein each photon-sensitive layer is

in one of a plurality of states wherein each photon-sensitive layer is alterable at selected locations from one of two states to another state of two states, the apparatus comprising: at least one photon source; at least one controllable photon distributor; a controller connected to the photon source and the photon distributor and programmed to selectively activate at least one of the at least one photon source and to control the controllable photon distributor to expose at least one of the at least one photon-sensitive layers in a selected pattern across the surface thereby selectively revealing a selected subset of sub-pixels of the pixel pattern and portions of photon-sensitive layers thereby producing an image composed of the revealed sub-pixels and photon-sensitive layer portions.

15. An apparatus for producing on a medium a first image in a first image area and a second image in a second image area having a substrate with a surface printed with a first print-pixel area and a second print pixel area, the first print-pixel area being composed of colored sub-pixels that absorb and /or reflect visible light in a predetermined wavelength range when exposed to visible light; the second print pixel area being composed of colored fluorescent sub-pixels that emit in a predetermined wavelength range when exposed to UV light; and having at least one photon-sensitive layer covering the first and the second print-pixel areas and wherein each photon- sensitive layer is in one of a plurality of states wherein each photon-sensitive layer is alterable at selected locations from one of two states to another state of two states, the apparatus comprising: at least one photon source; at least one controllable photon distributor; a controller connected to the photon source and the photon distributor and programmed to selectively activate at least one of the at least one photon source and to control the controllable photon distributor to expose at least one of the at least one photon-sensitive layers in a selected pattern across the surface thereby selectively revealing a selected subset of sub-pixels of the first and the second pixel pattern and portions of photon-sensitive layers thereby producing an image composed of the revealed sub-pixels and photon-sensitive layer portions.

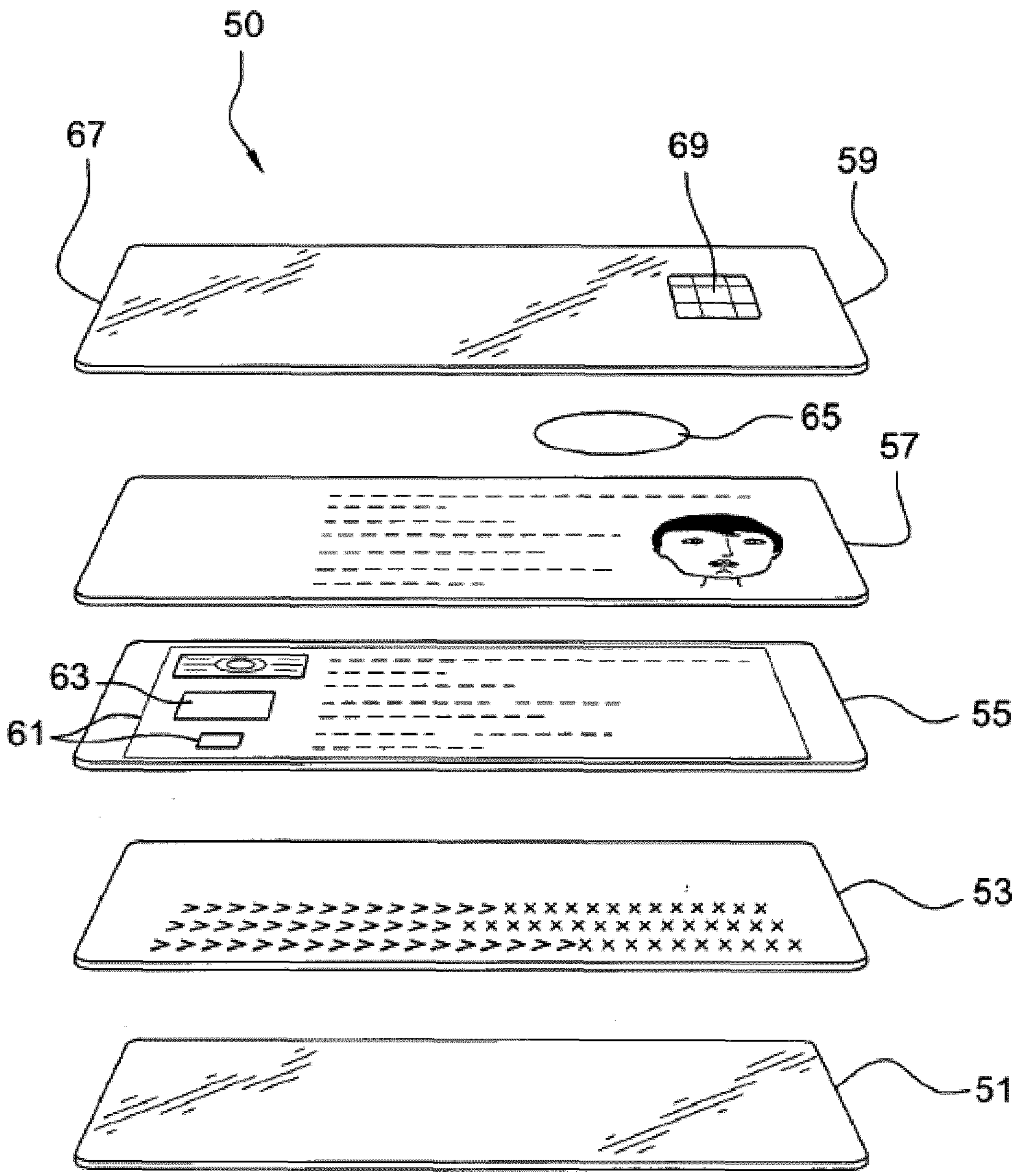

Fig. 1

(Prior Art)

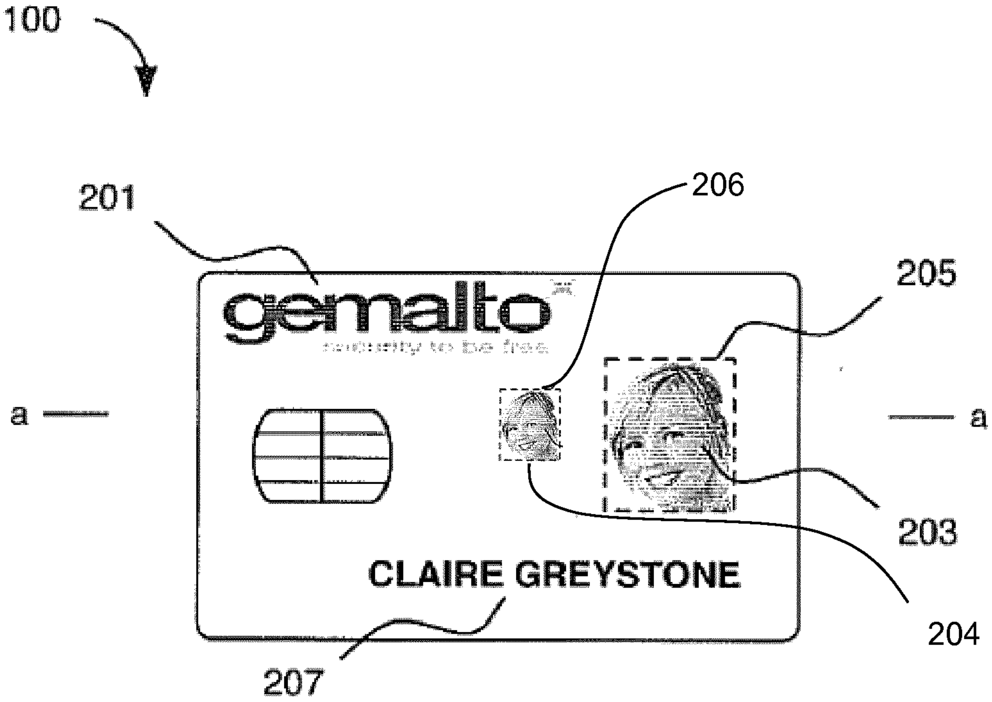
100
201
206
205
gemalto
security to be free
a
a
203
CLAIRE GREYSTONE
204
207

Fig. 2

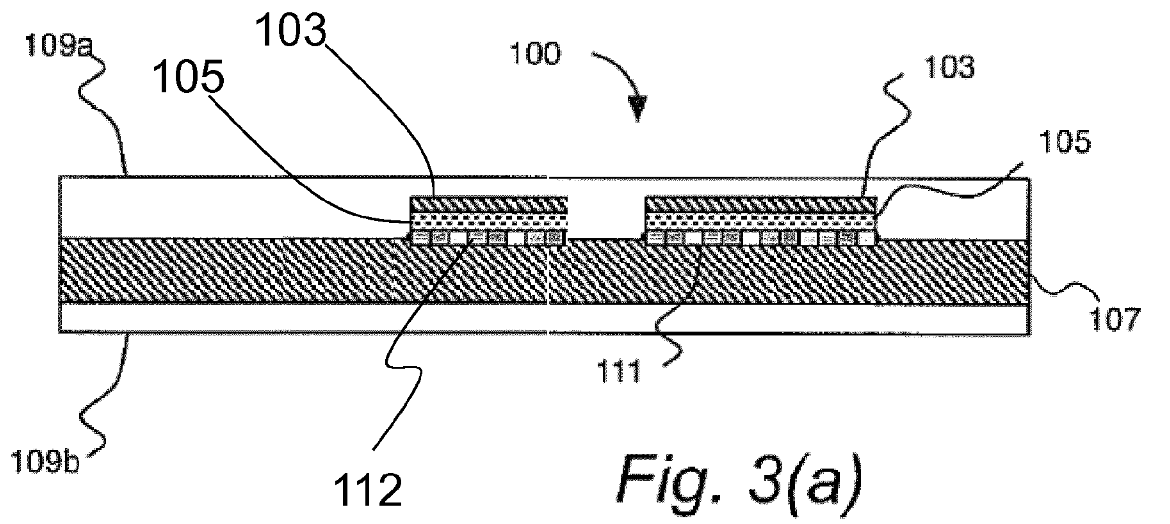
109a
103
105
100
103
105
107
111
109b
112

Fig. 3(a)

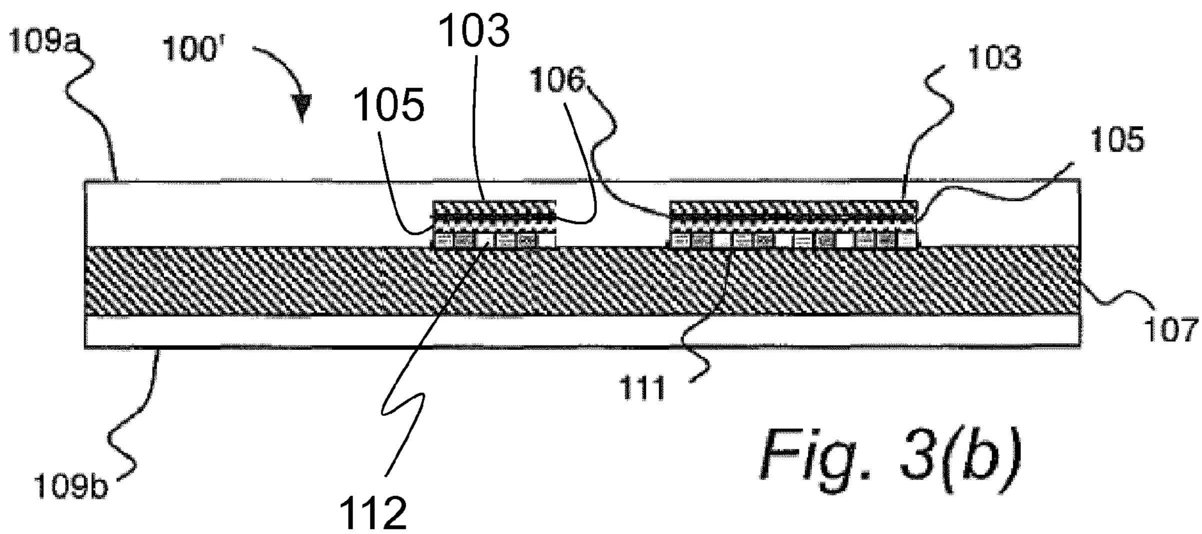
109a
100'
103
105
106
103
105
107
111
109b
112

Fig. 3(b)

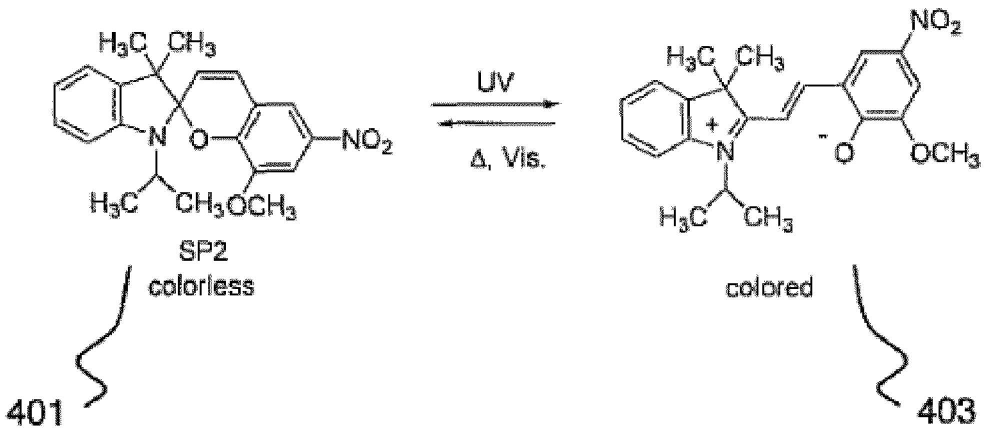
H3C CH3
N
O
NO2
H3C CH3 OCH3
SP2
colorless
UV
Δ, Vis.
NO2
H3C CH3
+
N
O
OCH3
H3C CH3
colored
401
403

Fig. 4

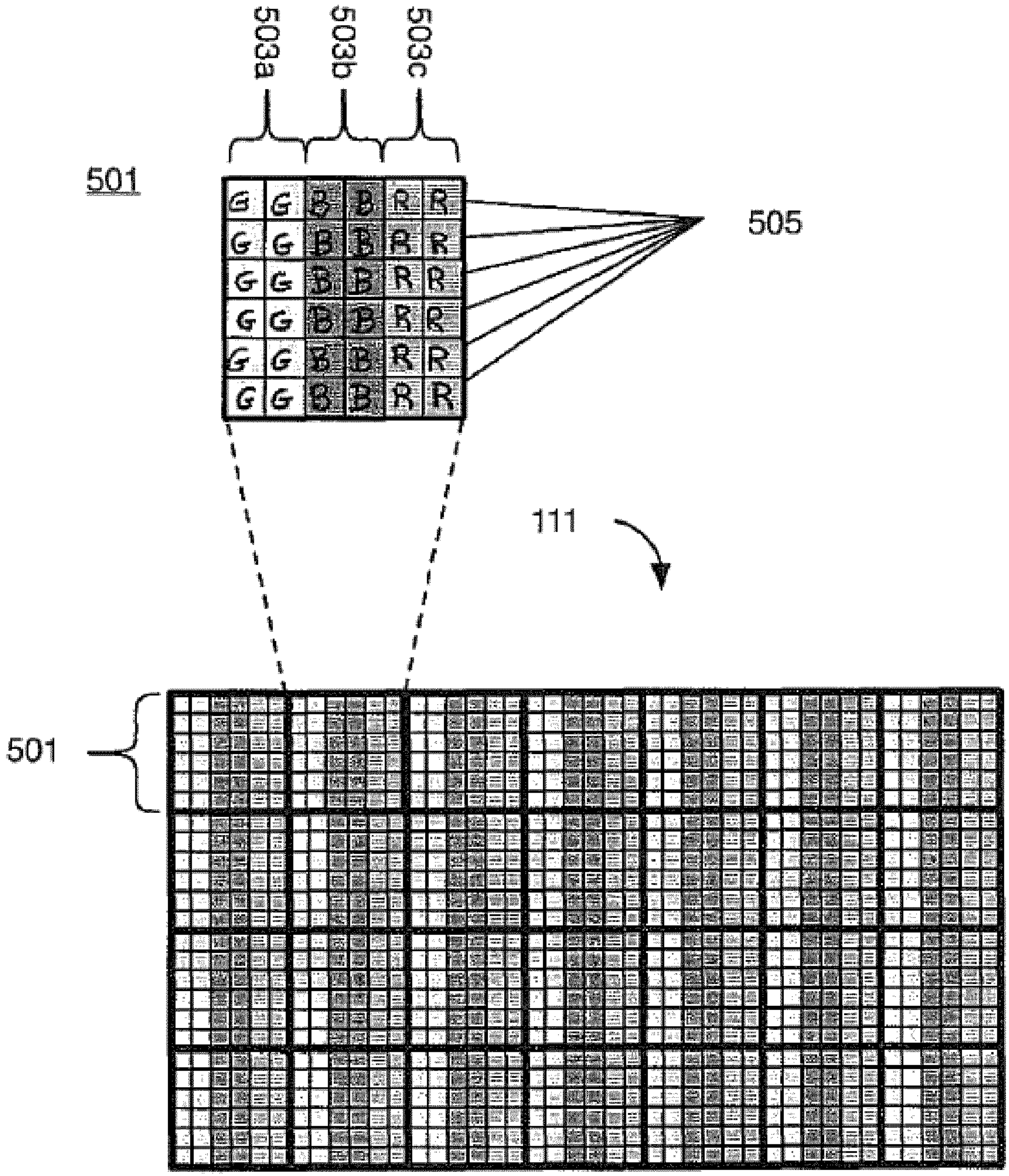

Fig. 5

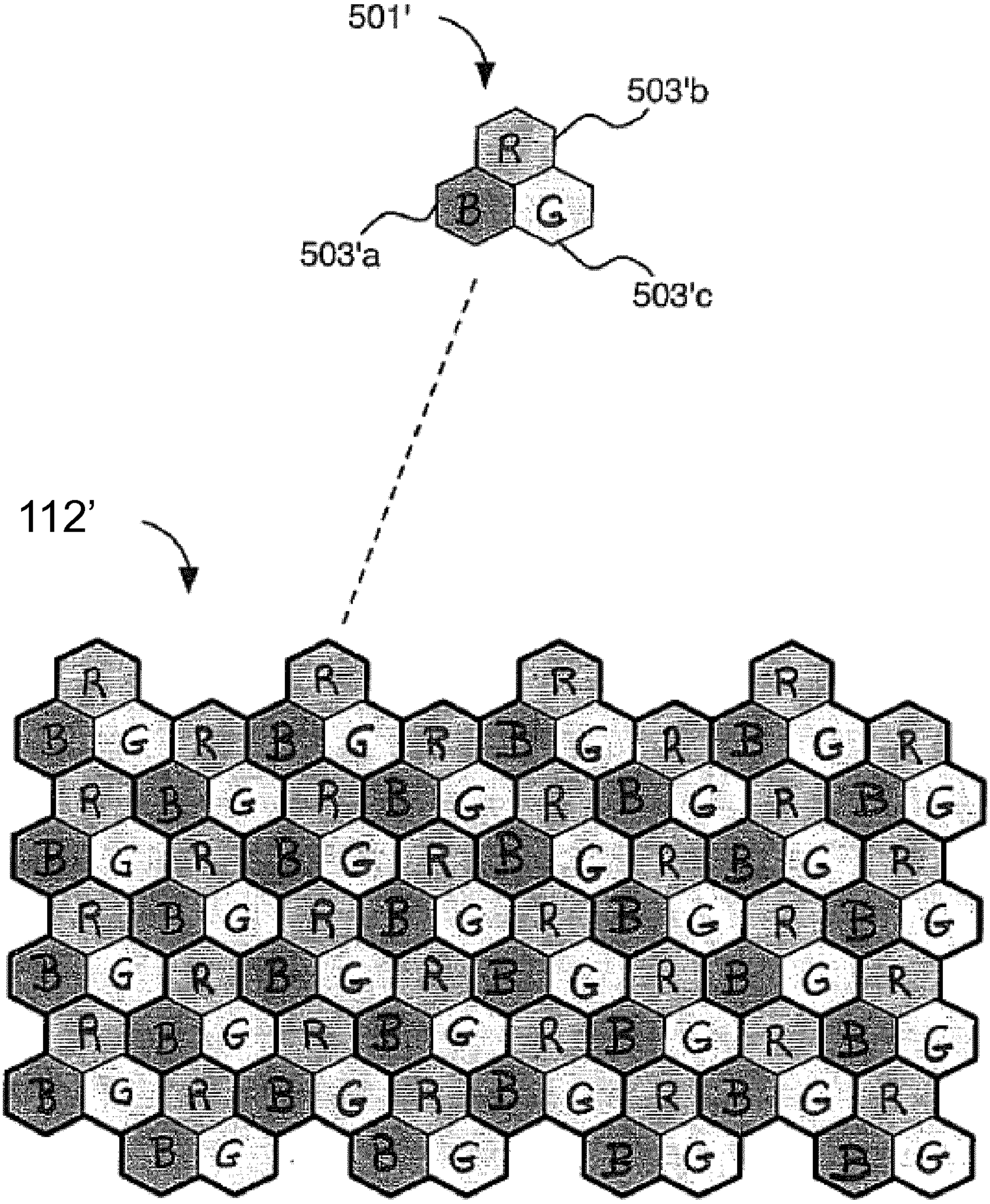

Fig. 6(a)

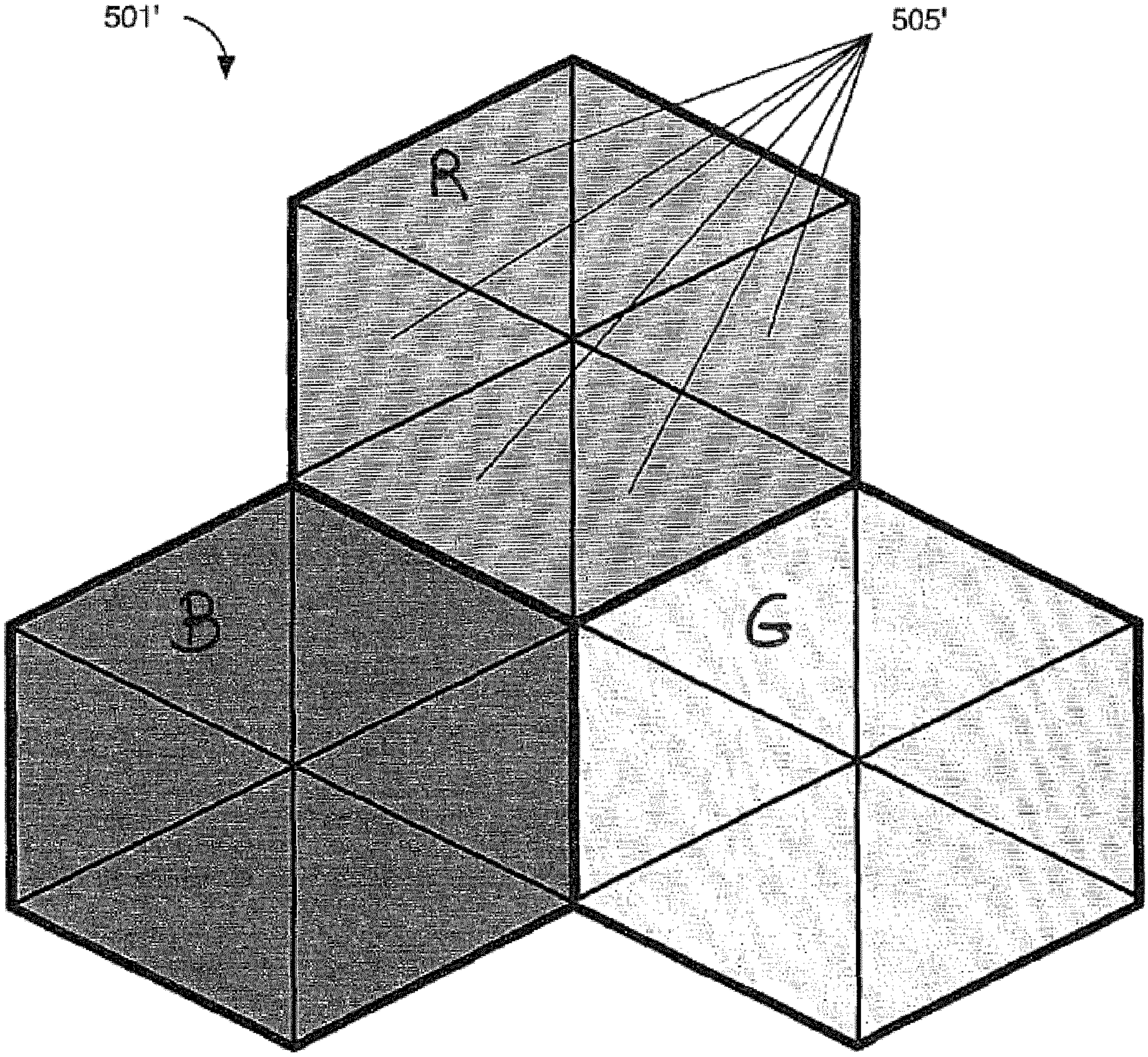

Fig. 6(b)

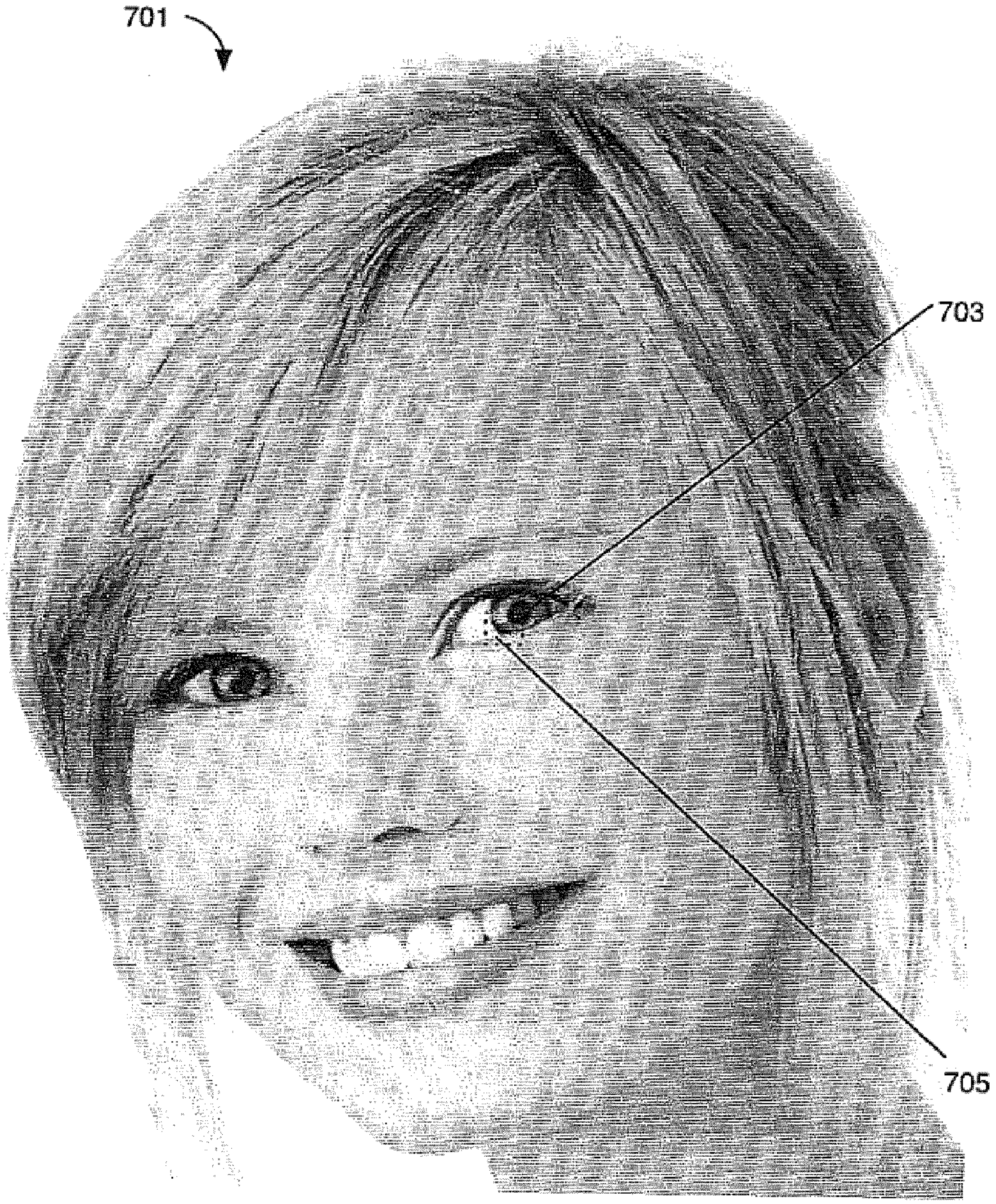

Fig. 7

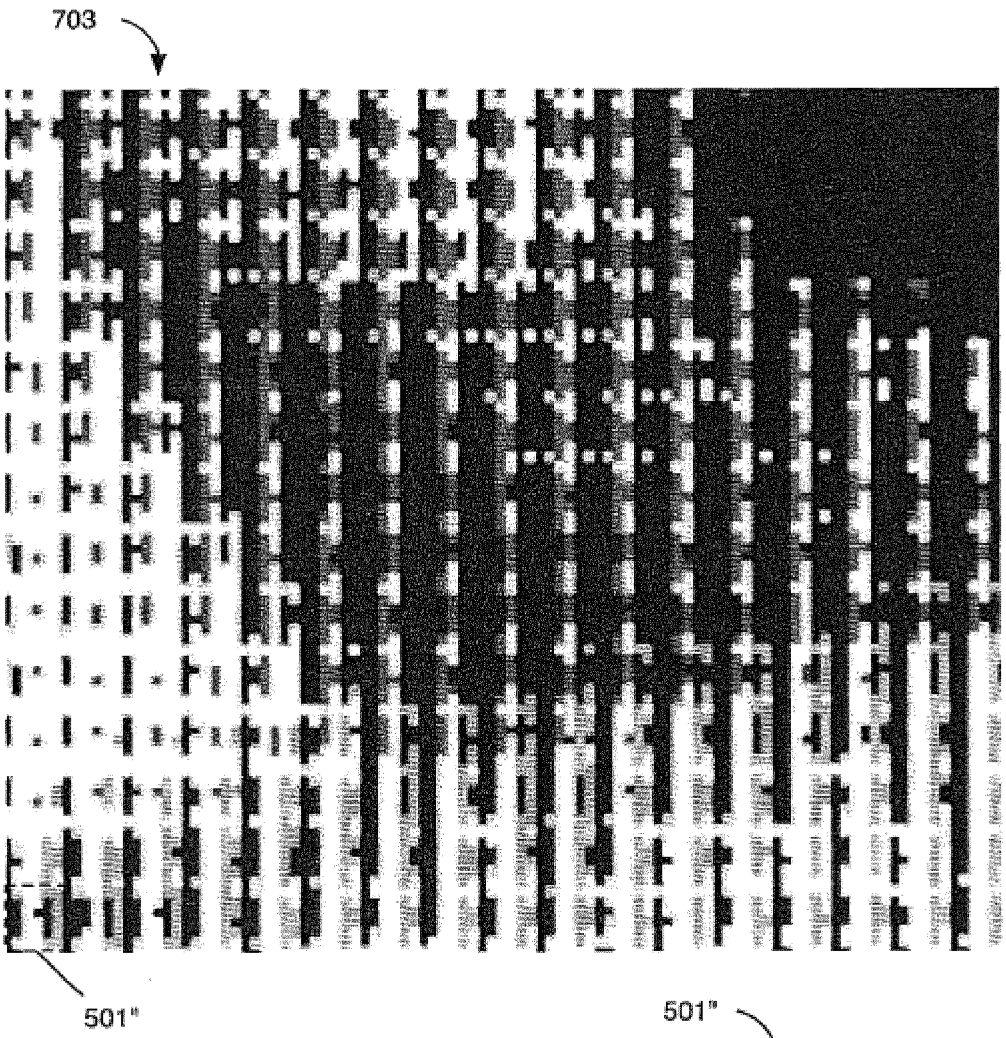

Fig. 8(a)

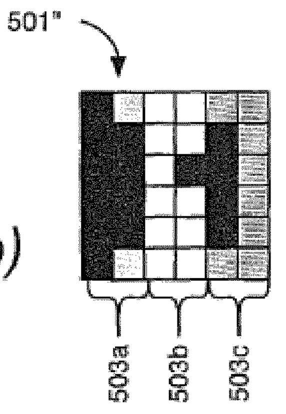

Fig. 8(b)

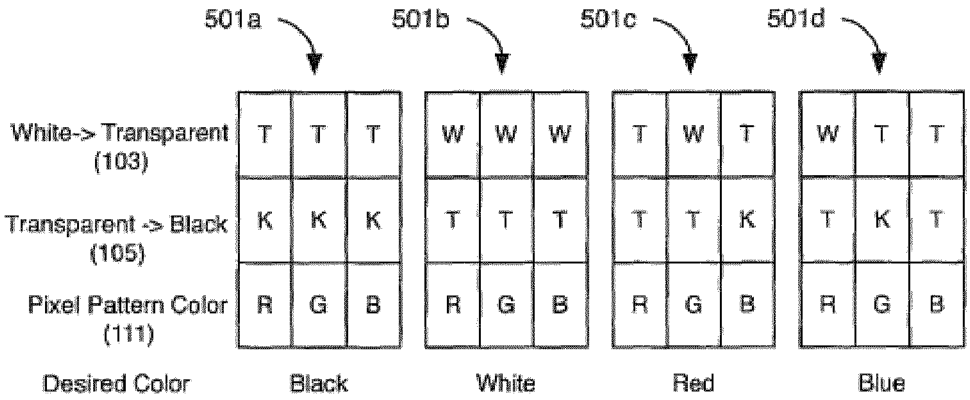
501a
501b
501c
501d
White-> Transparent (103)
Transparent -> Black (105)
Pixel Pattern Color (111)
Desired Color
T T T
K K K
R G B
Black
W W W
T T T
R G B
White
T W T
T T K
R G B
Red
W T T
T K T
R G B
Blue

Fig. 9 (a)

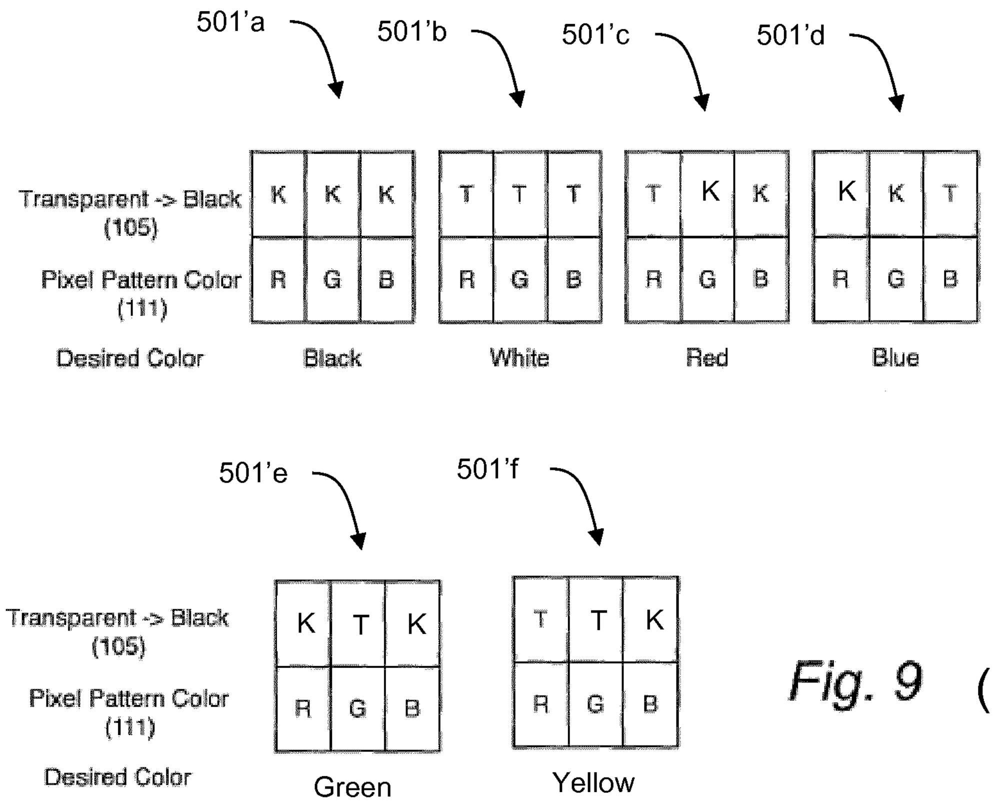
501'a
501'b
501'c
501'd
Transparent -> Black (105)
Pixel Pattern Color (111)
Desired Color
K K K
R G B
Black
T T T
R G B
White
T K K
R G B
Red
K K T
R G B
Blue
501'e
501'f
Transparent -> Black (105)
Pixel Pattern Color (111)
Desired Color
K T K
R G B
Green
T T K
R G B
Yellow

Fig. 9 (b)

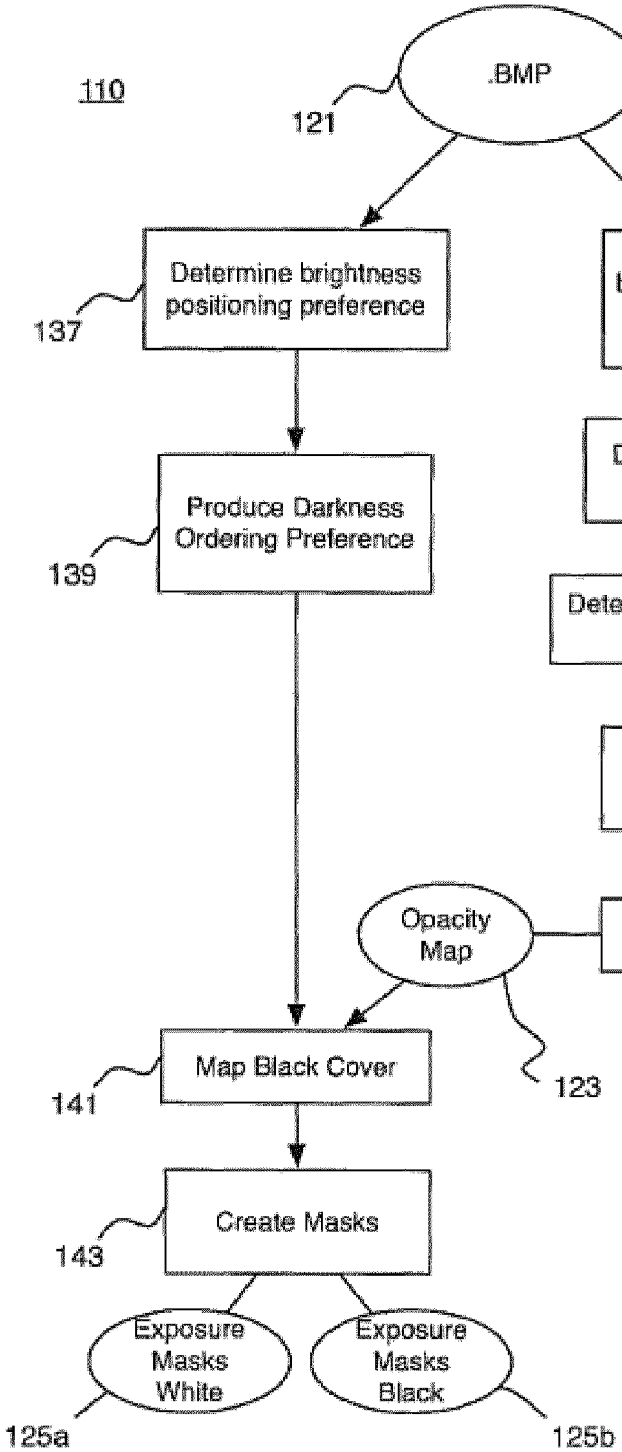
110
.BMP
121
Determine brightness positioning preference
137
Determine brightness for source pixels (*source brightness)*
127
Produce Darkness Ordering Preference
139
Determine *white level adjusted RGB*
129
Determine hue enhancement of each printpixel
131
Brightness Correction
133
Opacity Map
Map Opacity
135
Map Black Cover
141
123
Create Masks
143
Exposure Masks White
Exposure Masks Black
125a
125b

Fig. 10

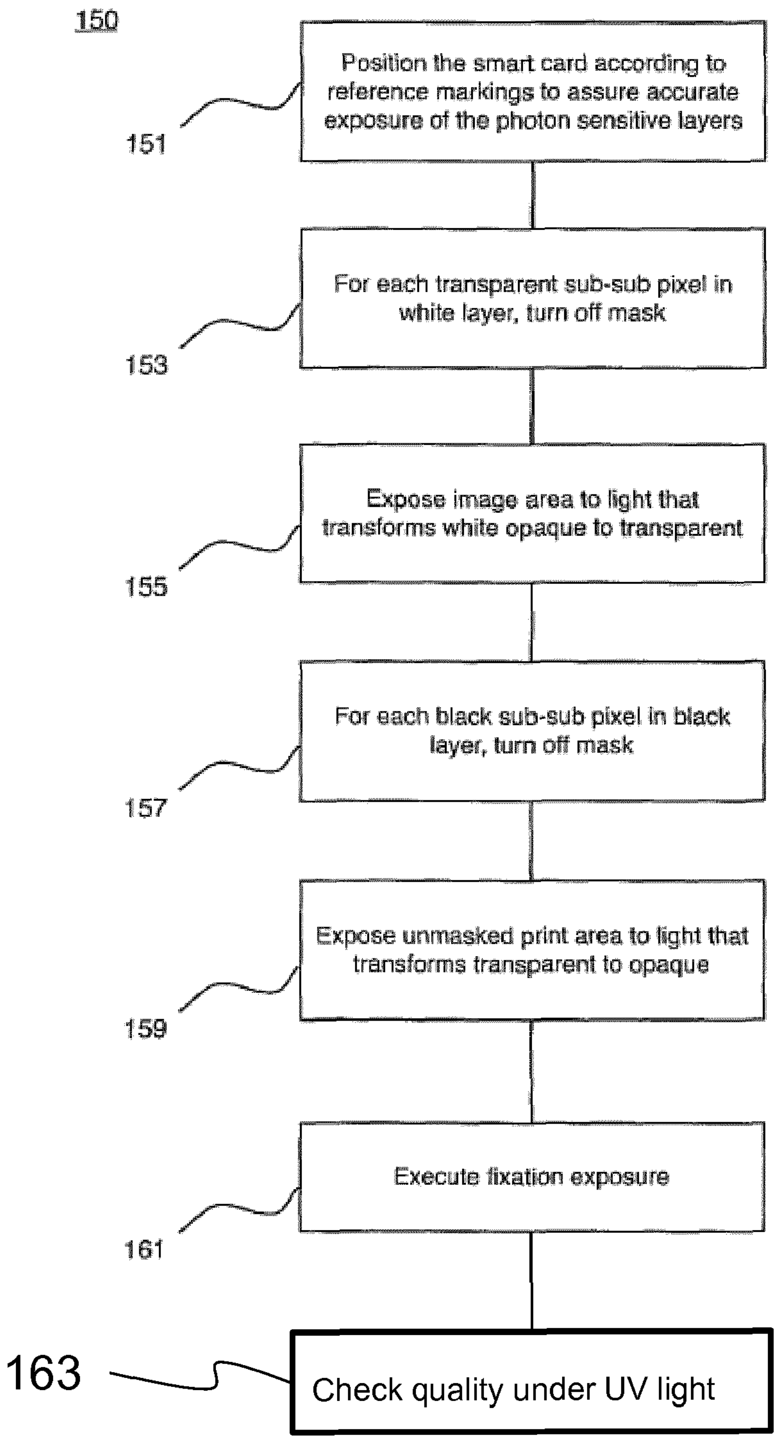
150
Position the smart card according to reference markings to assure accurate exposure of the photon sensitive layers
151
For each transparent sub-sub pixel in white layer, turn off mask
153
Expose image area to light that transforms white opaque to transparent
155
For each black sub-sub pixel in black layer, turn off mask
157
Expose unmasked print area to light that transforms transparent to opaque
159
Execute fixation exposure
161
163
Check quality under UV light

Fig. 11

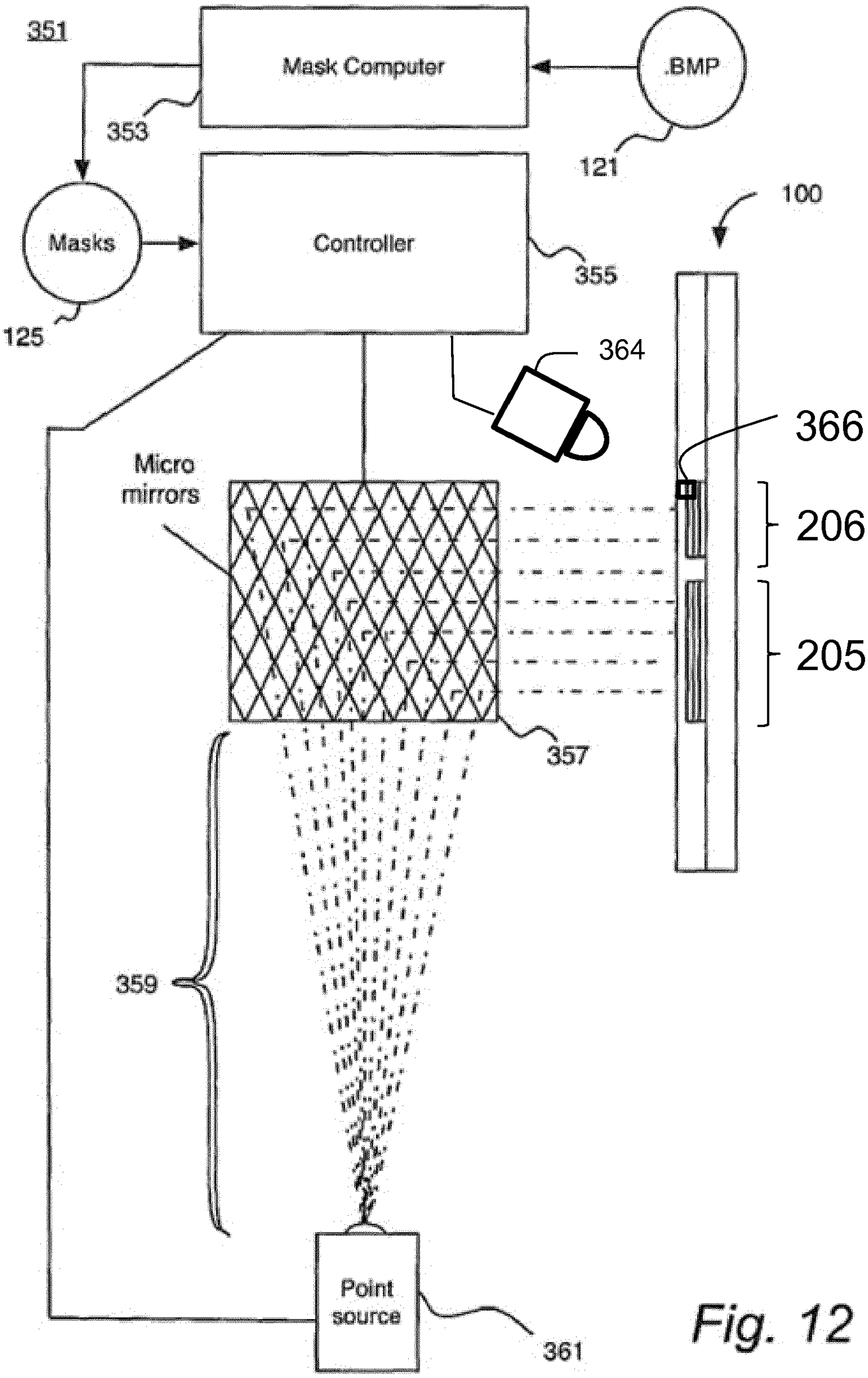
351
Mask Computer
.BMP
353
121
Masks
Controller
100
355
125
364
366
Micro mirrors
206
205
357
359
Point source
361

Fig. 12

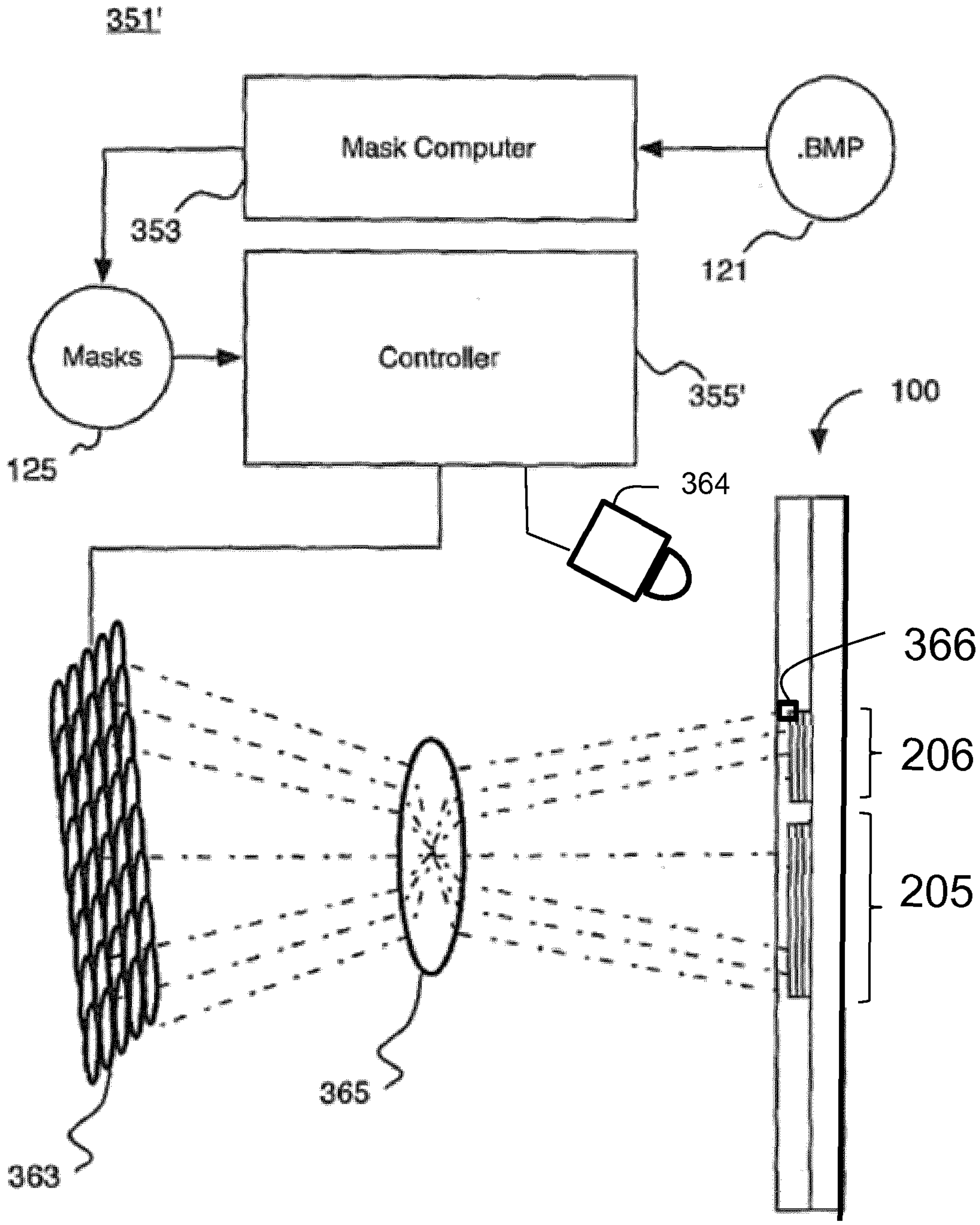
351'
Mask Computer
.BMP
353
121
Masks
Controller
355'
100
125
364
366
206
205
365
363

Fig. 13

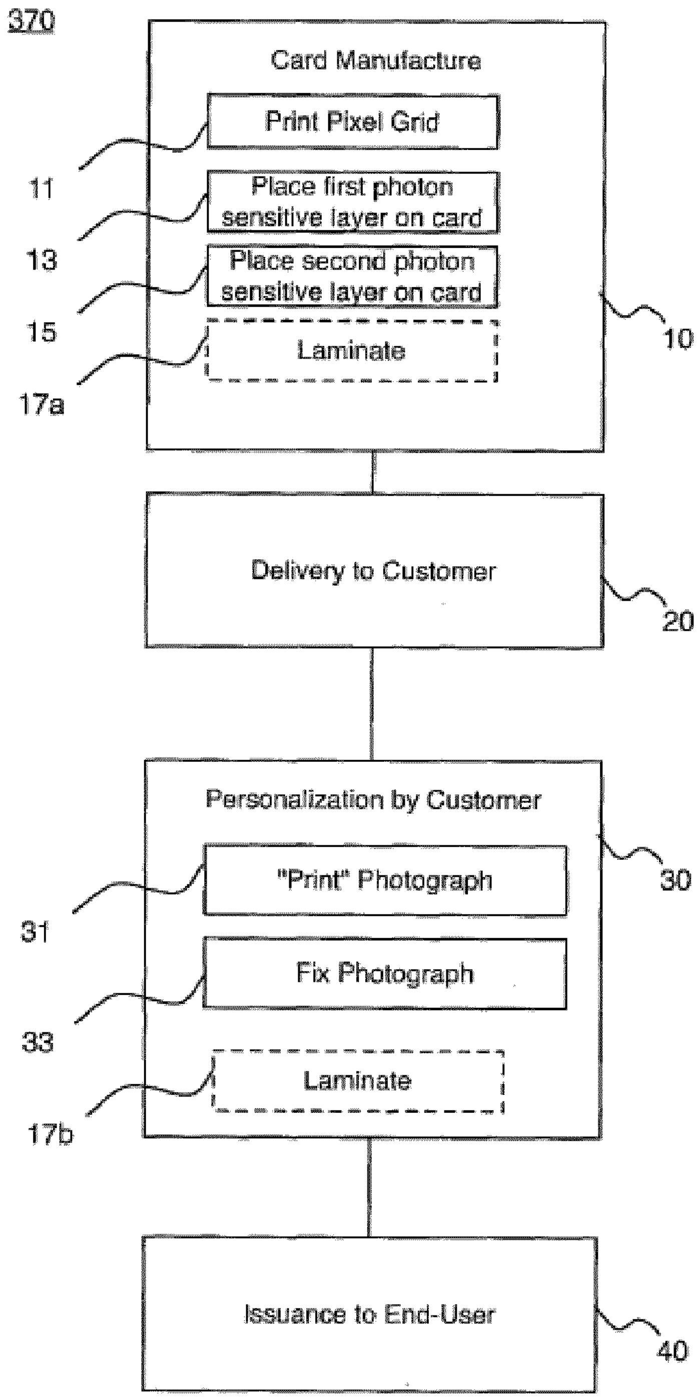
370
Card Manufacture
Print Pixel Grid
Place first photon sensitive layer on card
Place second photon sensitive layer on card
Laminate
11
13
15
17a
10
Delivery to Customer
20
Personalization by Customer
"Print" Photograph
Fix Photograph
Laminate
30
31
33
17b
Issuance to End-User
40

Fig. 14

Europäisches Patentamt
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EUROPEAN SEARCH REPORT

Application Number
EP 14 19 9021

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
Y,D	WO 2011/045180 A1 (GEMALTO SA [FR]; LEIBENGUTH JOSEPH [FR]; LESUR JEAN-LUC [FR]; BOMBAY B) 21 April 2011 (2011-04-21) * paragraph [0013] - paragraph [0098]; claims 1-14; figures 1-11 *	1-7	INV. B42D25/387 B42D25/382 B42D25/36 B42D25/309 B42D25/41 B41M3/14 G07D7/12
Y	EP 2 747 406 A1 (GEMALTO SA [FR]) 25 June 2014 (2014-06-25) * column 11 - column 77; claims 1-5; figures 1-7 *	1-7	
Y	US 2006/201362 A1 (DUMERY THIERRY [FR] ET AL) 14 September 2006 (2006-09-14) * paragraph [0002] - paragraph [0039]; claims 10-18; figure 1 *	1-7	
Y	WO 2009/056355 A1 (BUNDESDRUCKEREI GMBH [DE]; LEOPOLD ANDRE [DE]; MUTH OLIVER [DE]; FISCH) 7 May 2009 (2009-05-07) * page 3, line 26 - page 37, line 26; claims 1-50; figures 1-4 *	1-7	
			TECHNICAL FIELDS SEARCHED (IPC)
			B42D B41M

~~The present search report has been drawn up for all claims~~

2

Place of search	Date of completion of the search	Examiner
Munich	27 May 2015	Seiler, Reinhold

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

Europäisches Patentamt
European Patent Office
Office européen des brevets

Application Number

EP 14 19 9021

CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing claims for which payment was due.

☐ Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due and for those claims for which claims fees have been paid, namely claim(s):

☐ No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due.

LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

see sheet B

☐ All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.

☐ As all searchable claims could be searched without effort justifying an additional fee, the Search Division did not invite payment of any additional fee.

☐ Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:

☒ None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:

1-7

☐ The present supplementary European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims (Rule 164 (1) EPC).

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European Patent Office
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LACK OF UNITY OF INVENTION SHEET B

Application Number
EP 14 19 9021

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

1. claims: 1-7

   A method for producing an image.

   ---

2. claims: 8-13

   A personalizable medium.

   ---

3. claims: 14, 15

   An apparatus for photon exposure of a surface.

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 14 19 9021

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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27-05-2015

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2011045180 A1	21-04-2011	EP 2488370 A1	22-08-2012
		JP 2013508186 A	07-03-2013
		KR 20120087947 A	07-08-2012
		US 2011090298 A1	21-04-2011
		WO 2011045180 A1	21-04-2011
EP 2747406 A1	25-06-2014	NONE	
US 2006201362 A1	14-09-2006	CN 1832865 A	13-09-2006
		EP 1651448 A1	03-05-2006
		FR 2858582 A1	11-02-2005
		MA 27913 A1	02-05-2006
		OA 13231 A	13-12-2006
		US 2006201362 A1	14-09-2006
		WO 2005021277 A1	10-03-2005
WO 2009056355 A1	07-05-2009	DE 102008012423 A1	07-05-2009
		WO 2009056355 A1	07-05-2009

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 7368217 B, Lutz **[0011]**
- US 20050161512 A **[0014]**
- US 8314828 B **[0015] [0068] [0078]**
- US 2004259975 A **[0090]**

Non-patent literature cited in the description

- **J. ROBILLARD et al.** *Optical Materials,* 2003, vol. 24, 491-495 **[0090]**