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(54) **METHOD FOR MANUFACTURING PERSONALISED OPTICAL DOCUMENT SECURITY ELEMENTS AND THE ELEMENT OBTAINED**

(57) The invention relates to a method for manufacturing personalized optical document security elements and element obtained, the method comprising using confinement surfaces (1, 2), wherein at least one of the confinement surfaces (1, 2) contains a pattern of electrodes (4) and an alignment layer (5) on its inner side, arranging a liquid crystal (3) doped with at least one dichroic dye between the confinement surfaces (1, 2), applying an electric field to the electrodes (4) to orient the liquid crystal

(3) according to the voltage applied by each electrode (4), applying light to the liquid crystal (3) through the confinement surfaces (1, 2) until the liquid crystal (3) is polymerized, stopping application of the electric field to the electrodes (4), such that a transparent polymerized liquid crystal film with at least one personalized latent image obtained by applying the electric field to the electrodes (4) is obtained between the confinement surfaces (1, 2).

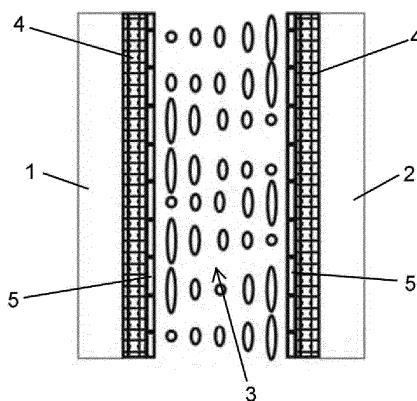


FIGURE 1

Description

Sector of the art

[0001] The present invention relates to manufacturing transparent, optically variable optical document security elements working by liquid crystal-based transmission, for being applied in documents such as banknotes, checks, credit cards, identification documents or similar documents. The manufacturing method of the invention allows obtaining optical document security elements containing different sets of latent images on each of their sides which can be viewed independently by means of polarized light, at least one of the images of at least one of the sides of the element being unique and personalized for that element. The developed method allows personalizing the optical element in a cost- and time-efficient manner, favoring the serial production for mass industrial production. The optical element obtained allows validating original documents by adding an additional security level through individual personalization of the document.

State of the art

[0002] The demand for security elements for protecting banknotes, credit cards, identification documents and official documents or products of value of any type is constantly on the rise due to increasingly more accessible quality counterfeiting techniques.

[0003] The optically variable security elements are indispensable in any everyday official document for protecting end users, given that they require no advanced technical knowledge or particular skills for verification. In this regard, many technologies and solutions have been used, where those that are most popular and widely used are holograms, variable security inks or watermarks.

[0004] The development of optically variable security elements based on liquid crystal material has gradually expanded in recent decades and is widely used in the protection of official documents such as legal tender banknotes or identification documents.

[0005] For example, document US7316422B1 presents a security measure in which a layer of thermotropic liquid crystal is deposited on a translucent layer together with liquid crystal pigments such that different color effects in reflected light are produced upon a change of viewing angle. Likewise, temperature changes cause a change in the layer of thermotropic liquid crystal, making it transition from an opaque to a translucent state.

[0006] The use of cholesteric liquid crystals in security measures having a color variation effect has also been widely used such as in, for example, documents EP2010007368, WO/2010/00364, or the more recent WO/2014/06115.

[0007] However, all these first security measures were developed to work in reflected light, being applied directly on opaque surfaces, rendering them unsuitable for being inserted in the transparent windows incorporated in-

creasingly more in banknotes and identification documents in recent years.

[0008] Some liquid crystal security measures were subsequently developed for being applied in transparent windows. However, their integration in the transparent area of the window considerably reduces transparency and prevents clearly seeing what is on the other side through said window, furthermore presenting the same optical effect when viewed from both sides of said window.

[0009] Document US20080106725A1 has a security measure with a liquid crystal layer that linearly polarizes light, entailing a decrease in transparency and presenting the same polarization effect on both sides.

[0010] Document EP2508358A1 solves the two problems contemplated above as it presents a completely transparent monolayer security measure with different sets of latent images on each side that are independent from one another both in design terms and during the viewing process. Later documents WO2017060544A1 and WO2017009494A1 move forward in the same direction, presenting security devices with different latent images on each side working in transmission and presenting completely transparent areas at all times.

[0011] However, all these security measures have a limitation resulting from the fact that they cannot be individually personalized for each document they protect. Therefore, the personalization of the documents must be done through other techniques, such as printing serial numbers or laser engraving, among others. Although these solutions do allow individualizing the protected document, they diminish the robustness of the security measure given that because it can be extracted from the document, it could be used for being integrated in another fraudulent or adulterated document.

[0012] Therefore, the demand for the possibility of personalizing visual security measures by techniques or processes that enhance robustness thereof is growing, being an indispensable requirement on occasion, as in the case of solutions intended for identification documents.

[0013] Therefore, the present invention intends to solve this problem by allowing the individualized personalization of each optical security element in a cost-efficient manner and without slowing down the production process.

Object of the invention

[0014] The invention proposes a new method for manufacturing optical document security elements such as those described in EP2508358A1, WO2017060544A1 and WO2017009494A1, which allows the personalization of at least one image of the optical document security element manufactured.

[0015] The optical document security elements described in the documents mentioned above work in transmission and have different latent images on each side,

the images being independent from one another both in design and in their viewing and can be verified by using polarized light. The elements are in the form of an extremely thin and flexible monolayer film, furthermore being transparent though colored at all times. In the manufacturing method described in EP2508358A1, the latent images of the elements are defined by a fixed or permanent pattern containing multiple micrometer-scale alignment regions, thus allowing the efficient, large-scale manufacture thereof.

[0016] The proposed invention describes a new manufacturing method that allows reconfiguring the alignment pattern to create at least one individually personalized image on at least one side of the element without interrupting production processes, such that it is time- and cost-efficient.

[0017] The method for manufacturing personalized optical document security elements comprises the steps of:

- using confinement surfaces, wherein
 - at least one of the confinement surfaces contains a pattern of electrodes and an alignment layer on its inner side,
- arranging a liquid crystal doped with at least one dichroic dye between the confinement surfaces,
- applying an electric field to the electrodes to orient the liquid crystal according to the voltage applied by each electrode,
- applying light to the liquid crystal through the confinement surfaces until the liquid crystal is polymerized,
- stopping application of the electric field to the electrodes,
 - such that a transparent polymerized liquid crystal film with at least one personalized latent image obtained by applying the electric field to the electrodes is obtained between the confinement surfaces.

[0018] A reconfigurable alignment pattern is established between the electrodes and the alignment layer, such that at least one of the confinement surfaces, that is, the one containing a pattern of electrodes and an alignment layer on its inner side, can be reused for manufacturing a new optical element without the need to modify the structure of the confinement surface, and images different from those produced in previous iterations can therefore be produced for manufacturing a new element.

[0019] The personalized image can present a high degree of complexity if the application or design thus requires it, containing, for example, the high-definition portrait of the official identification document holder. It is also possible to produce simple images that require reconfigurable patterns, such as consecutive serial numbers. The obtained film is thin, flexible, colored and transparent, made of polymerized (mesogenic) liquid crystal doped with dichroic dye and contains the different latent images on each side, which can be viewed by polarized light, at least one of said images being the image that is person-

alized with a unique specific design.

[0020] In one embodiment, both confinement surfaces have the pattern of electrodes and the alignment layer on their inner side, such that a film with at least one personalized latent image is obtained on each side of the film.

[0021] In another embodiment, only one of the confinement surfaces has the pattern of electrodes together with the alignment layer on its inner side, and the other confinement surface has a fixed alignment layer without electrodes for defining a pre-established and therefore not reconfigurable orientation of the liquid crystal. A film is thereby obtained with at least one personalized latent image on just one side of the film and with at least one pre-established latent image on the other side.

[0022] The film can be extracted from the confinement substrates if it is suitable for the application, or the optical element finally obtained can be the film confined between the confinement substrates, or one of them can be removed, such that the optical element finally obtained is the film together with one of the confinement substrates.

[0023] The film obtained may comprise a protective polymer film covering and helping to protect same.

[0024] The latent images of each of the sides of the film are visible independently and without interfering with one another during the verification process by using linearly polarized light. The light used is normally the light emitted by the display of commonly used consumer devices, such as a Smartphone mobile telephone or an LCD display. The images can likewise be viewed using low-cost external means such as a linear polarizer with natural light. Another form of verification that avoids the use of external elements consists of using a beam coming from the reflection of light on a dielectric surface (partially polarized light).

[0025] The film does not present any visible image when observed with natural (depolarized) light. The latent images, which become visible when the device is illuminated with polarized light, are different on each side of the film and do not interfere with one another during the viewing process. The images can be solid (B/W) or with a grayscale of up to 256 levels as for resolution, where they may furthermore be monochrome or in color.

[0026] The confinement surfaces have different alignment directions on their inner sides following a pattern corresponding to the latent images to be generated after the necessary image processing, which, in general, gives rise to multiple zones with alternating twist structures and homogeneous structures in the liquid crystal volume contained between both surfaces. The polymerizable liquid crystal molecules are oriented forming these structures in volume together with the dichroic dye molecules which are ordered integrally with the liquid crystal molecules. This configuration of the polymerizable liquid crystal and the dichroic dye conditions the behavior of the polarized light when it goes through the film, giving rise to the characteristic visual effect of the technology.

[0027] If the film is illuminated with linearly polarized

light, the dichroic dye molecules aligned according to a specific direction absorb the polarized light in that direction and it is not absorbed by the molecules oriented perpendicular to that absorption direction. The dichroic dye molecules are aligned in a manner consistent with the liquid crystal molecules in volume according to the orientation induced on facing surfaces. Since the twist structure rotates the linear polarization of the light, regardless of the volumetric structure induced in the film (twist or homogeneous), whether or not the linearly polarized incident light is absorbed will only depend on the orientation of the dye molecules on the light inlet surface and on the polarization direction thereof. Thus, the film selectively absorbs the polarized light according to the alignment direction of the dichroic dye and liquid crystal molecules at the inlet, obtaining a dark state, whereas it lets the polarized pass through perpendicular to same, obtaining a light state. Therefore, for a given incident polarization, one set of images is shown, and if the incident light polarization direction or the sample is rotated, another different set of images will be observed. If the polarized light enters through the other side of the film, the operation is similar, and another set of different images can be seen in the absence of interference with the images of the opposite side. The film is transparent at all times (it is possible to see through it) to natural light and during the verification process.

[0028] The orientation of the liquid crystal by means of the pattern of electrodes in the zones of the confinement surfaces which allows producing personalized images can be obtained by using one of the following two techniques:

- Alignment by means of a pattern of reconfigurable interdigitated electrodes which can be independently directed for each pixel and allows performing in-plane switching of the confinement surfaces combined with a homogeneous alignment layer parallel to the interdigitated electrodes on the confinement surfaces.
- Alignment by means of a unique pattern of interdigitated electrodes combined with a homogeneous alignment system parallel to the pattern of interdigitated electrodes and sequential polymerization by zones.

[0029] The first technique for producing the personalized images comprises using an electrode array arranged on the inner side of at least one of the two confinement surfaces and an alignment layer arranged on the electrodes wherein a preferred alignment direction is defined. The electrode array is designed such that for each pixel of the personalized image to be created there are a series of electrodes which are parallel to the induced preferred alignment direction in the alignment layer covering these electrodes. The pixels associated with the electrode array can be as small as desired and the electrodes can be directed individually, for example by

an active array. The pixel size limit in terms of efficiency is the resolution that can be distinguished by the human eye (exceeding 800 ppi), and the size thereof can be reduced if desired.

[0030] By means of digitally processing the personalized images to be included in the optical security element, the image files compatible with the described configuration are produced such that the images are translated to gray levels (up to 256 levels). The personalized images are evaluated pixel-by-pixel by determining the discrete gray level of each one and associating each pixel with the voltage to be applied to the electrodes associated with it. Upon application of the voltage, the liquid crystal molecules together with the dichroic dye molecules will be aligned on the surface of the confinement substrates following the pattern induced by the electric field, departing a certain angle from the preferred direction predefined by the alignment layer covering the electrode array. Thus, for a specific incident light polarization, the image is formed in grayscale in a manner that is individualized for each optical element.

[0031] The delay time needed for the liquid crystal doped with dichroic dye to be oriented upon application of the electric field is directly related to the voltage value applied between electrodes and to the temperature of the liquid crystal at that time. This voltage value must maintain a compromise, since excessively high values can cause out-of-plane switching of the liquid crystal, causing a scattering effect and irreversible loss of transparency in definition in the personalized images. As for the temperature of the material, that is, the mixture of liquid crystal and dichroic dye, it must be controlled so that it is stabilized in the highest zone within the nematic range. A lower viscosity is thereby achieved and the re-ordering of the molecules upon application of the electric field is faster. Once the liquid crystal is oriented, it is polymerized with UV light and the confinement surfaces can be removed to extract the flexible film obtained. The confinement substrates containing the pattern of electrodes can be reused to produce a new different personalized image for the following element.

[0032] It is possible for the liquid crystal doped with the dichroic dye not to be in direct contact with the electrode array, and the electric field can go through an additional layer sandwiched between the electrodes and the liquid crystal. This additional layer must be very thin (a few micra) for the electric field to be able to go through it without needing to reach high voltage values. The use of higher voltage values can cause out-of-plane switching of the liquid crystal, causing undesired optical effects. This additional sandwiched layer can be used as a support which in turn carries out protective functions both for the film obtained and for the electrode array, preventing adherence between same.

[0033] Furthermore, the invention contemplates the possibility of producing a visible and unique barcode or serial number in each optical element produced, this being a form of individualized personalization itself that is

in turn combinable with the personalization by means of latent images described above. To that end, an electric field is applied between at least one of the electrodes of one of the confinement surfaces and at least one of the electrodes of the other confinement surface. The liquid crystal is thereby oriented in those areas in the direction perpendicular to the plane of the confinement substrates during the curing process. Its implementation is simple and the produced image (barcode or serial number) is visible by means of natural light. By means of polarized light, maximum contrast is obtained for one inlet light polarization direction, whereas the image is not visible for the perpendicular polarization direction. Furthermore, the viewed image is correct when it is observed from one of the sides, but when it is observed from the opposite side, the mirror image is seen.

[0034] The second technique for producing personalized images comprises applying UV light for polymerizing the film in two sequential steps. In one step, UV light is selectively applied according to the personalized image to be obtained, with the personalized image being encoded in shades of black and white; in said step, regions of the liquid crystal are illuminated and polymerized, with other regions of the liquid crystal being left unpolymerized; and in another subsequent step, the electric field is applied to the electrodes to orient the liquid crystal in the unpolymerized regions, and UV light is then applied to said regions so as to polymerize them.

[0035] A structure of interdigitated electrodes parallel to one another is used to induce a single orientation to the dichroic dye and liquid crystal molecules upon application of the electric field, such that upon application of the voltage, the molecules are oriented perpendicular to the electrodes and parallel to the plane of the confinement surface. The confinement surface in which the electrodes are defined has an alignment layer superimposed on the excitation lines of the electrodes, in which a homogeneous alignment in the direction parallel to the direction of the electrodes has previously been induced by rubbing or another similar technique.

[0036] According to one embodiment, a B/W image is projected onto the liquid crystal doped with the dichroic dye confined between the substrates, which corresponds with the personalized image to be produced. To that end, a DLP (digital light processing) projection system individually illuminating those regions to be polymerized in a first curing step is used, i.e., the regions corresponding with the liquid crystal molecules aligned by the preferred alignment layer deposited on the electrodes are illuminated, keeping those regions to be cured in a second step in shadow. The DLP projection system requires additional software for mechanical adjustment of the system, if needed, and subsequent depth focus of the image with respect to the layer of the active material, maintaining its resolution and sharpness. The first curing step can be performed by means of an external UV light source at the suitable wavelength or by adding this external source to the DLP projection system.

[0037] In a second step, projection of the B/W image is stopped and the electric field is applied to the electrodes to modify the alignment of the liquid crystal molecules not yet polymerized. With the electric field applied, the entire surface is illuminated with UV light such that the liquid crystal molecules oriented by the field are polymerized in the direction perpendicular to the preferred direction, thus producing the desired personalized image.

[0038] Similarly, the order of the process can be reversed, obtaining the same result. That is, according to another embodiment, the negative of the B/W image is projected, and the electric field is applied to the electrodes first, reordering the liquid crystal molecules doped with dichroic dye, the illuminated regions then being polymerized with UV light. Then the electric field and the projection of the B/W image is removed, the unpolymerized molecules returning to their relaxed state and original orientation according to the preferred direction induced by the layer deposited on the electrodes. Then the entire surface is illuminated to polymerize the remaining regions.

[0039] The electrodes are defined on the inner side of at least one of the confinement surfaces by one of the following techniques: photolithography; selective laser ablation; nanometer printing, or a combination of the foregoing, among others.

[0040] The alignment layers have one or more alignment directions defined by one of the following techniques: masks; physical barriers; mechanical rubbing; selective deposition; thermal evaporation; inkjet; or a combination of the foregoing.

[0041] The invention contemplates being able to produce the alignment directions induced in both confinement surfaces using the same technique, different techniques or combinations of several techniques.

[0042] Additionally, a rigid or flexible RGB color array can be added to the element for the purpose of providing it with color (any color in contrast with the monochrome version). Furthermore, it is contemplated that the color array is placed matching up the zones defined in the film with the pixels defined in the RGB array and that the RGB array is placed on the outer side of the polymerized film or on the inner side of a protective polymer film covering the optical element.

[0043] It is possible for the alignment directions to have relative orientations at 0°, 45°, 90° and 135° to produce two monochrome images without overlap in the viewing process (individually visible on one and the same side) on one or both sides of the monolayer film. The alignment directions can have different relative orientations comprised between 0° and 90° to produce images in gray-scale (up to 256 levels) on at least one of its sides.

Description of the figures

[0044] Different embodiments of the invention according to different processes applied, as well as the optical

elements resulting from same are depicted in the figures.

Figure 1 shows an assembly for manufacturing personalized optical document security elements according to an embodiment of the invention including two confinement surfaces with their respective alignment layers defining the pattern giving rise to the latent images. The liquid crystal doped with dichroic dye is located in the space comprised between both surfaces.

Figure 2 shows another system for manufacturing the optical elements according to another embodiment of the invention in which the possibility of the alignment pattern not being in direct contact with the polymerizable liquid crystal by including a thin separation layer is included. Likewise, it includes the possibility of one of the two surfaces having a preferred alignment layer different from the pattern of interdigitated electrodes. Said alignment layers are conventionally used in manufacturing elements based on liquid crystal.

Figure 3 shows an embodiment of the invention in which the latent images of one side are produced with a complex pattern of interdigitated electrodes directed by software.

Figure 4a shows the arrangement of the polymerizable liquid crystal molecules following the alignment induced by the interdigitated electrodes according to the embodiment described in Figure 3 for the produced latent image to be a letter (capital letter 'A'). Figure 4b shows the result of the viewing of the resulting device according to the embodiment of the invention described in Figure 4a upon illumination of the optical security element with polarized light from the side opposite the side that was in contact with the pattern that contained the viewed image.

Figure 5 shows the structure of one of the confinement surfaces of the device according to one of the embodiments of the invention. It consists of a simple pattern of interdigitated electrodes for in-plane switching, being covered by an alignment layer with a preferred direction induced according to the arrow by mechanical rubbing or other techniques.

Figure 6 shows the orientation of the molecules on the surface according to the embodiment of the invention relating to Figure 5. For the selective curing of the polymerizable liquid crystal molecules following the design of the personalized image, use of a DLP projection system along with its corresponding positioning and focus software, as well as the prior image treatment of the design selected for the individualized personalization are required. Use of a physical mask, UV laser beam or any selective polymerization technique with the design of the latent image to be produced is also contemplated.

Figure 7 shows the final orientation of the polymerizable liquid crystal on the surface after applying the electric field through the pattern of electrodes for

modifying the orientation of the molecules that were in shadow (or covered by the physical mask) in Figure 6 and their subsequent polymerization by means of UV light.

Figure 8 shows a device for manufacturing the optical elements in which the polymerizable liquid crystal molecules doped with dichroic dye have a vertical or homeotropic orientation (perpendicular to the surface of the confinement substrates) in one or more zones to produce simple codes for unitary identification and/or serialization.

Figure 9 shows the result of viewing the resulting optical element according to the embodiment of Figure 8 upon illumination of one of the sides of the optical element with depolarized and linearly polarized light (orthogonal directions coinciding with the alignment of the molecules in the plane).

Figure 10 shows a simulation of a personalized high-resolution image valid for any of the embodiments of the invention.

Detailed description of the invention

[0045] The invention proposes an alternative process for manufacturing an optical document security element which allows the individualized personalization of at least one of its sides.

[0046] The manufacturing method uses two rigid or flexible confinement surfaces (1, 2) according to Figure 1, between which there is arranged a polymerizable liquid crystal (3) doped with at least one dichroic dye. At least one of the two confinement surfaces (1, 2) has on its inner side zones in which electrodes (4) and an alignment layer (5) deposited on the pattern of electrodes are defined, between which a reconfigurable alignment pattern is established. The alignment layer (5) has a fixed alignment pattern, whereas the electrodes (4) are configured for applying an electric field which allows orienting the liquid crystal (3) in the alignment layer (5) according to a pattern designed for producing at least one personalized image.

[0047] When the liquid crystal (3) is arranged between the confinement surfaces (1, 2), the liquid crystal (3) is oriented according to the fixed pattern established by the alignment layer (5), and when the electric field is applied to the electrodes (4), the liquid crystal (3) is oriented in the alignment layer (5) according to the voltage applied by each electrode (4), then the liquid crystal (3) is polymerized by means of UV radiation of a suitable wavelength, and when the liquid crystal (3) is polymerized, application of the electric field is stopped, such that the liquid crystal (3) that is already polymerized is permanently oriented according to the designed pattern containing the personalized latent image.

[0048] In this manner, a flexible, colored and transparent film formed by the polymerized liquid crystal in which at least one of the sides of the film obtained contains a personalized latent image is obtained between the con-

finement surfaces (1, 2).

[0049] Figure 1 shows the vertical cross-section of a device for manufacturing personalized optical document security elements. The device is formed by two confinement surfaces (1, 2) on the inner sides of which the electrodes (4) and the preferred alignment layers (5) are defined. The polymerizable liquid crystal (3) doped with dichroic dyes is contained between the confinement surfaces (1, 2). The confinement surfaces (1, 2) can be flexible or rigid. The liquid crystal (3) will present twist structures rotated an angle between 90° or -90° according to the configuration of the alignment patterns defined in both surfaces of the confinement substrates (1, 2). The complete grayscale between dark and light colors (B/W) can thus be achieved. For the sake of simplicity, Figure 1 only depicts the configuration that would produce B/W images on each side of the film finally obtained. The doped liquid crystal is in contact with both inner sides of the confinement surfaces (1, 2) so as to achieve an optimal alignment in the entire volume before the liquid crystal is polymerized by means of UV irradiation. To that end, the doped liquid crystal can be introduced between the confinement surfaces (1, 2) or deposited on one of the surfaces and subsequently placed in contact with the other surface.

[0050] In the specific case of producing personalized latent images by means of the electrodes (4), the alignment of the molecules can be induced without direct contact between the electrodes and the liquid crystal (3) by making the electric field go through an additional separation layer (7) between both, preventing at all times out-of-plane switching.

[0051] Figure 2 shows the vertical cross-section of another device for manufacturing personalized optical document security elements. The device is formed by two confinement surfaces (1, 2); the pattern of electrodes (4) is defined on the inner side of one of the confinement surfaces (1) and the alignment layer (5) is deposited, on which the additional layer (7) separating the liquid crystal (3) from the inner side of the confinement surface (1) is added, thereby getting the electric field to go through the additional layer (7) and reorder the liquid crystal molecules (3), as out-of-plane switching must be prevented at all times. A fixed alignment layer (6) is defined on the inner side of the other confinement surface (2), such that with this device a film having at least one personalized latent image is obtained on one of the sides obtained by one of the techniques described above, and at least one pre-established latent image is obtained on the other side obtained by means of alignment patterns commonly used in liquid crystal devices.

[0052] Figure 3 shows a depiction of the possibilities offered by the first technique. It is a complete structure of interdigitated electrodes to which the electric field is selectively applied through a directing system. By means of an ad hoc developed software tool, the image to be created in the element is processed, and the electrode array that will be activated upon application of the electric

field is configured. Once the electric field is applied, the polymerizable liquid crystal doped with dichroic dye is oriented and immediately thereafter polymerized by irradiating with UV light. The applied electric field must be maintained until polymerization is completed. Once the liquid crystal is polymerized, the electric field is removed and the film is extracted from the confinement surfaces, which can be used again in the following iteration with a different configuration set to the new personalized image to be produced. By means of this embodiment of the invention, high-resolution, grayscale personalized images can be individually produced.

[0053] Figure 4a shows an example of the orientation of the polymerizable liquid crystal molecules. In this case, it is a basic image with B/W shades, without grayscale. Figure 4b shows the appearance of an optical element with the structure described in Figure 4a on one of its sides depending on the incident light polarization direction in each case (using a dye with positive dichroism). In this example, since the relative angle in absolute value between the light polarization direction and the orientation of the molecules is always 90° , gray levels are not observed.

[0054] Figures 5 to 7 illustrate the embodiment of the invention which uses the second technique using a simple pattern of electrodes parallel to one another, for in-plane switching of the liquid crystal, and it is combined with a conventional technique to induce a complementary alignment. The techniques used to induce this alignment can be, among others, mechanical rubbing, photoalignment or alignment by means of a physical submicrometer periodic or non-periodic pattern.

[0055] Figure 5 shows the cross-section of the structure of one of the confinement surfaces (1) used in this embodiment of the invention. A pattern of electrodes (4) parallel to one another for the in-plane switching of the mixture of liquid crystal and dichroic dye of the confinement surface (1) is defined, and defined on this pattern of electrodes (4) is an alignment layer (5) that can be formed by different rubbed polymers commonly used in the CL industry (polyimide, polyamide, PVA, PMMA, etc.), or a photoalignment material or a material on which there has been engraved a submicrometer periodic or non-periodic pattern, which induces a preferred alignment direction. It is thereby ensured that in the absence of an electric field between electrodes (4), the liquid crystal will be oriented following this alignment direction.

[0056] Figure 6 shows the orientation of the molecules of the polymerizable liquid crystal (3) doped with dichroic dye along the surface of the confinement substrate (1). The liquid crystal molecules (3) are oriented with their long axis parallel to the electrodes (4) in the absence of an electric field due to the preferred alignment induced by the alignment layer (5). The cross-section shows that in this step of the process a mask (8) is included to protect the zones of the liquid crystal that are not to be polymerized with UV light. A DLP projection system or a UV laser beam can also be used for the selective illumination

of the zones that are to be polymerized. The surface is illuminated with UV light and the liquid crystal molecules (3) that are exposed are polymerized, and they will remain fixed in the induced preferred alignment direction.

[0057] Figure 7 shows how the alignment of the unpolymerized liquid crystal molecules (3) changes as a consequence of applying the electric field, producing a difference in potential between alternating electrodes (4). The molecules (3) polymerized in the previous step of the process are not affected by the electric field. While keeping the electric field applied, the surface is radiated again with UV light such that the not yet polymerized liquid crystal molecules (3) are polymerized. The result will be a flexible monolayer film which contains the desired personalized latent image and can be extracted from the confinement surfaces (1, 2).

[0058] In the preceding figures, to obtain latent images an orientation of the liquid crystal molecules is induced in directions parallel to the plane of the confinement surfaces (1, 2), whereas Figure 8 shows an optical document security element according to an embodiment of the invention in which, in addition to the alignment in the plane, in certain regions a vertical alignment is induced in the liquid crystal molecules (3) doped with dichroic dye perpendicular to the confinement surfaces.

[0059] To that end, facing electrodes (4) in both confinement surfaces (1, 2) are used. Upon application of the electric field between the electrodes (4) facing the liquid crystal molecules (3), they are reordered by switching their position out of the plane of the confinement surfaces (1, 2). Individualized simple codes can thereby be produced for each optical element manufactured. The alignment pattern defined by the electrodes (4) will be selected depending on the type of code to be entered; in the event of a numerical code, a 7-segment pattern of electrodes will be used.

[0060] Figure 9 shows the visual effect of the embodiment of the invention described in Figure 8. The polymerizable liquid crystal molecules (3) oriented perpendicular to the planes of the confinement surfaces absorb the light (and therefore produce a dark state) at all times. For this reason, the code is visible upon illumination of the element on one of its sides with natural (unpolarized) light. Upon illumination of the element with polarized light, figures defined according to the pattern of interdigitated electrodes for switching the liquid crystal in the plane of the confinement surfaces will be observed, and the reverse version will be observed upon rotation of the polarization. In this case, the code will only be visible for one of the light polarizations (obtaining maximum contrast), whereas it is not visible for orthogonal polarization direction.

[0061] The invention has an application industrial as a document security element against the counterfeiting of banknotes, and/or in the authentication of documents including identification documents, credit cards, checks, or any element whose intrinsic value makes verification thereof advisable. The film obtained is completely trans-

parent to natural light at all times, although it will present coloring. The film contains different sets of latent images on each of its two sides, which images are independent from one another in design terms and can be viewed individually without interference between the sides during the verification process. At least one of the two sides will contain unique latent images personalized for that element. The verification is carried out by observing with polarized light the pattern of dark and light zones defining one or more images on each side, which will depend on the orientation of the liquid crystal at each point and on the polarization direction of the light going through it. The images can be high-resolution, grayscale and true color images, using an external RGB filter. The polarized light may come from a flat liquid crystal display, such as that of a mobile telephone, a tablet or a computer. Alternatively, an external linear polarizer can be used. Therefore, the security measure can be considered to be a level 1.5 measure, since it requires a commonly used element external for verification. Nevertheless, it can also be considered to be a level 1 measure, since it is sufficient to use using partially polarized light such as one coming from a grazing reflection on a polished surface, such as the floor or a table.

Claims

1. A method for manufacturing personalized optical document security elements, **characterized by** comprising the steps of:
 - using confinement surfaces (1, 2), wherein
 - o at least one of the confinement surfaces (1, 2) contains a pattern of electrodes (4) and an alignment layer (5) on its inner side,
 - arranging a liquid crystal (3) doped with at least one dichroic dye between the confinement surfaces (1, 2),
 - applying an electric field to the electrodes (4) to orient the liquid crystal (3) according to the voltage applied by each electrode (4),
 - applying light to the liquid crystal (3) through the confinement surfaces (1, 2) until the liquid crystal (3) is polymerized,
 - stopping application of the electric field to the electrodes (4),
 - such that a transparent polymerized liquid crystal film with at least one personalized latent image obtained by applying the electric field to the electrodes (4) is obtained between the confinement surfaces (1, 2).
2. The method for manufacturing personalized optical document security elements according to claim 1, **characterized in that** one of the confinement surfaces (1, 2) has the pattern of electrodes (4) and the alignment layer (5) on the inner side, and the other

confinement surface (1, 2) has a fixed alignment layer (6), such that a film is obtained with at least one personalized latent image on one side of the film and with at least one pre-established latent image on the other side.

3. The method for manufacturing personalized optical document security elements according to claim 1, **characterized in that** both confinement surfaces (1, 2) contain the pattern of electrodes (4) and the alignment layer (5) on the inner side, such that a film with at least one personalized latent image is obtained on each side of the film.

4. The method for manufacturing personalized optical document security elements according to any one of the preceding claims, **characterized in that** the polymerized liquid crystal film is extracted from the confinement surfaces (1, 2).

5. The method for manufacturing personalized optical document security elements according to any one of the preceding claims, **characterized in that** at least one confinement surface (1, 2) is flexible.

6. The method for manufacturing personalized optical document security elements according to any one of the preceding claims, **characterized in that** an additional separation layer (7) is arranged between the liquid crystal (3) and the inner side of the confinement surface (1, 2) containing the pattern of electrodes (4) and the alignment layer (5).

7. The method for manufacturing personalized optical document security elements according to any one of the preceding claims, **characterized in that** the pattern of electrodes (4) is defined on the inner side of at least one of the confinement surfaces (1, 2) by one of the following techniques:

photolithography;
selective laser ablation;
nanometer printing (printed electronics), or
a combination of the foregoing.

8. The method for manufacturing personalized optical document security elements according to any one of the preceding claims, **characterized in that** the alignment layers (5, 6) have alignment directions defined by one of the following techniques:

masks;

- physical barriers;

mechanical rubbing;

- selective deposition;

thermal evaporation;

- inkjet; or

a combination of the foregoing.

9. The method for manufacturing personalized optical document security elements according to any one of the preceding claims, **characterized in that** each pixel of the personalized latent image to be obtained is encoded according to a gray level, and **in that** each pixel of the personalized latent image is associated with a set of electrodes (4), such that the electric field applied to each set of electrodes (4) orients the liquid crystal (3) according to the pixel gray level associated with the set of electrodes (4).

10. The method for manufacturing personalized optical document security elements according to any one of claims 1 to 8, **characterized in that** light is applied to the liquid crystal (3) in two steps; in one step, light is applied according to the personalized latent image to be obtained, with the personalized latent image being encoded in shades of black and white; in said step, regions of the liquid crystal (3) are illuminated and polymerized, with other regions of the liquid crystal (3) being left unpolymersized; and in another step, the electric field is applied to the electrodes (4) to orient the liquid crystal (3) in the unpolymersized regions, and light is then applied to the entire surface, polymerizing the regions that had been left unpolymersized in the preceding step.

11. The method for manufacturing personalized optical document security elements according to the preceding claim, **characterized in that** the step of applying light according to the personalized latent image to be obtained is performed first, and the step of applying the electric field to the electrodes (4) is performed second.

12. The method for manufacturing personalized optical document security elements according to claim 10, **characterized in that** the step of applying the electric field to the electrodes (4) is performed first, and the step of applying light according to the personalized latent image to be obtained is performed second.

13. The method for manufacturing personalized optical document security elements according to any one of claims 3 to 12, **characterized in that** an electric field is applied between at least one of the electrodes (4) of one of the confinement surfaces (1, 2) and at least one of the electrodes (4) of the other confinement surface (1, 2), such that the liquid crystal (3) is oriented in the direction orthogonal to the plane of the confinement surfaces (1, 2).

14. A personalized optical document security element obtained by the method described in any one of the preceding claims.

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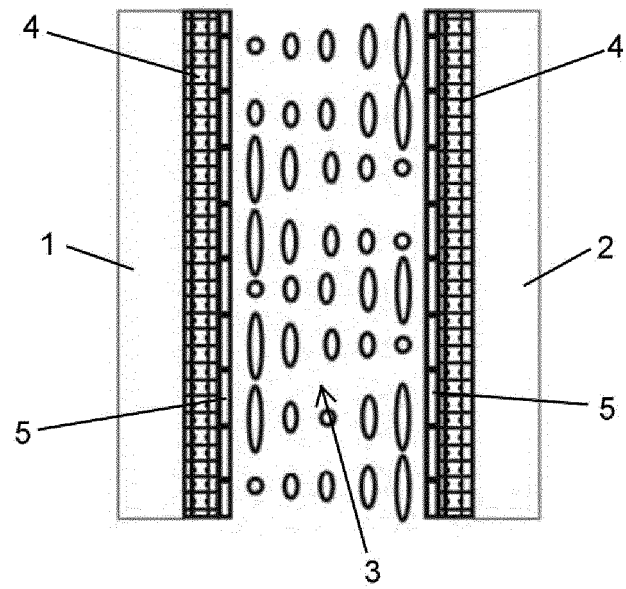


FIGURE 1

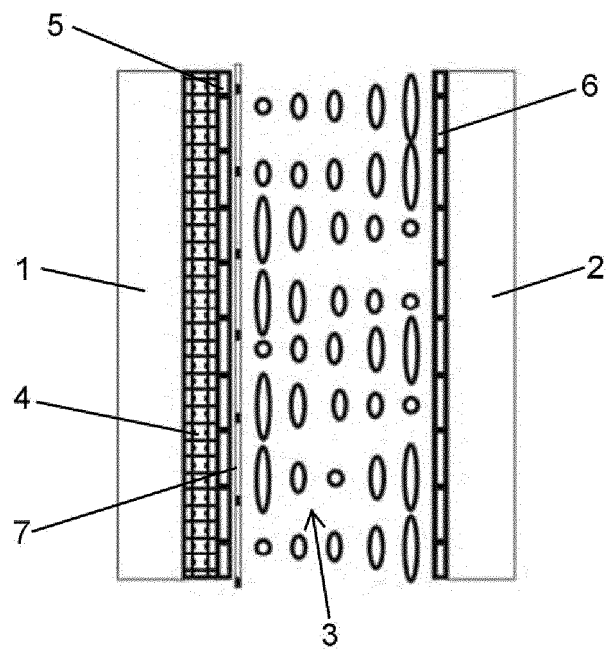


FIGURE 2

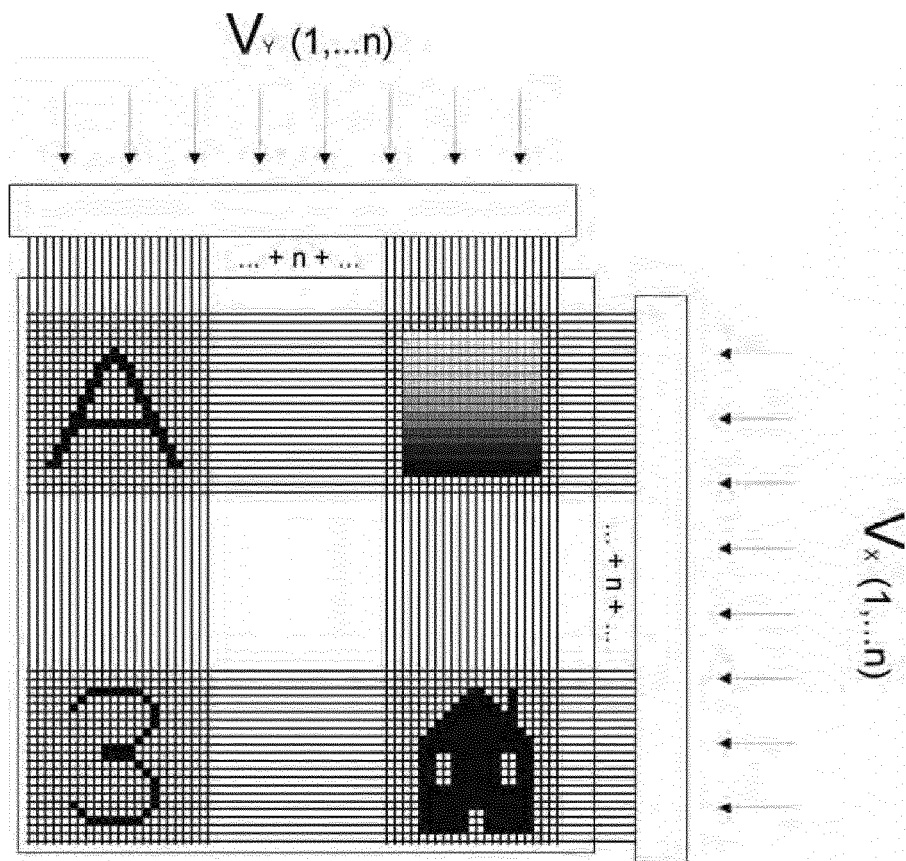


FIGURE 3

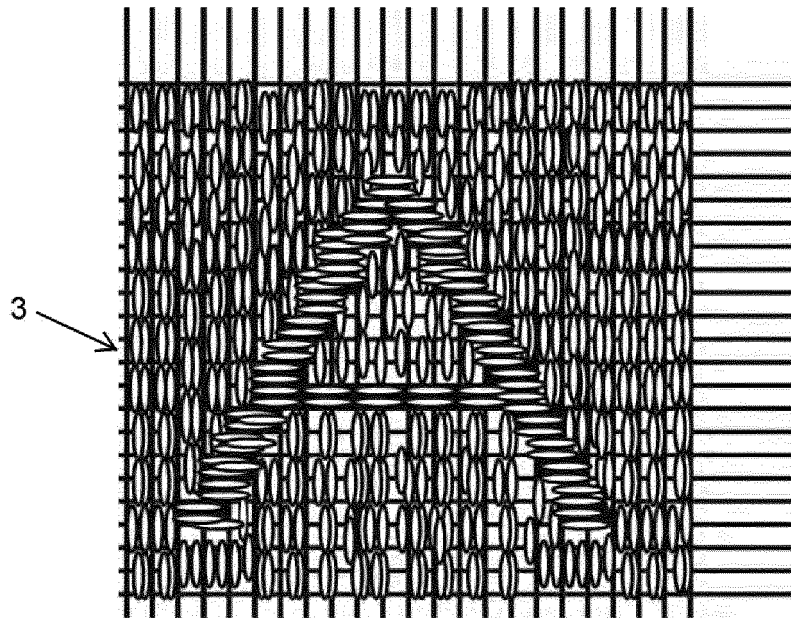


FIGURE 4

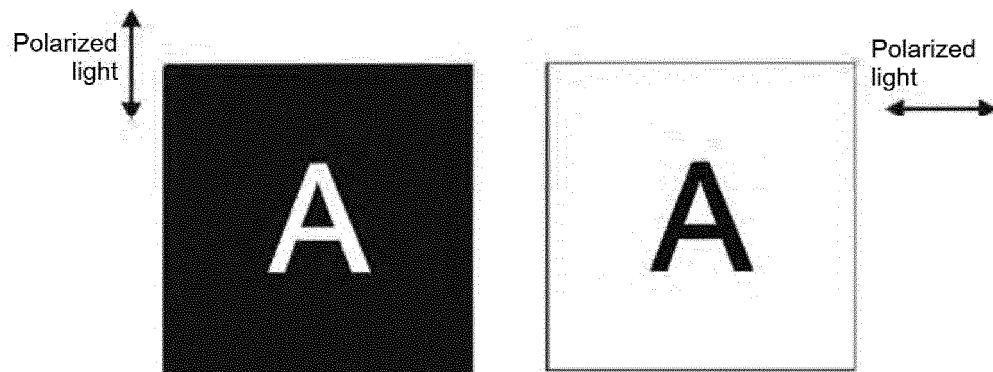


FIGURE 4B

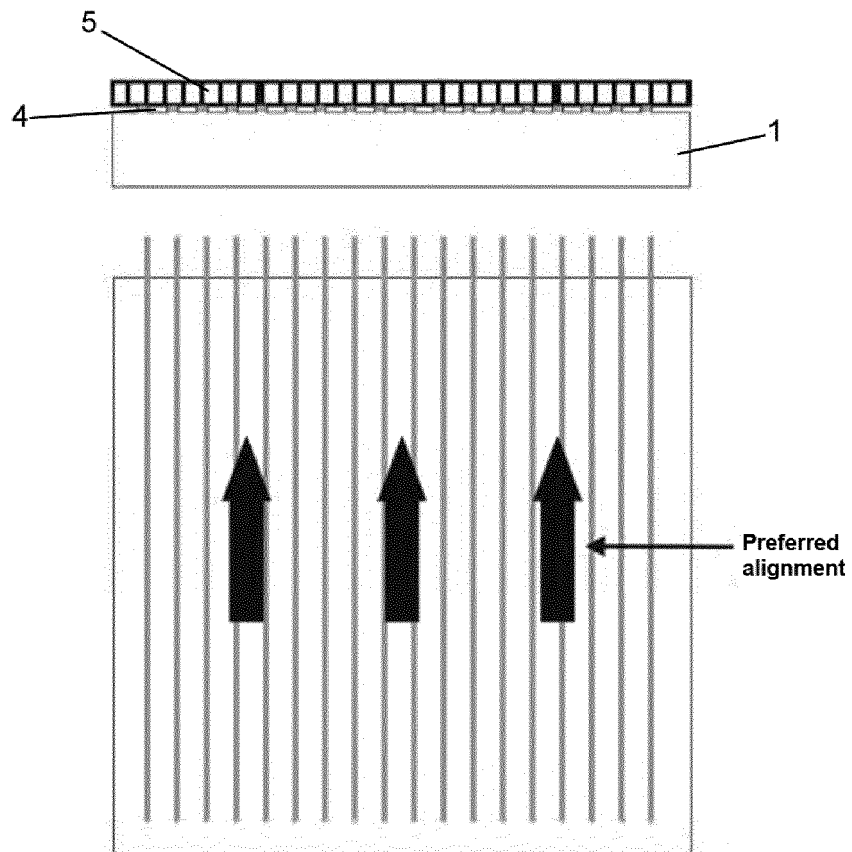


FIGURE 5

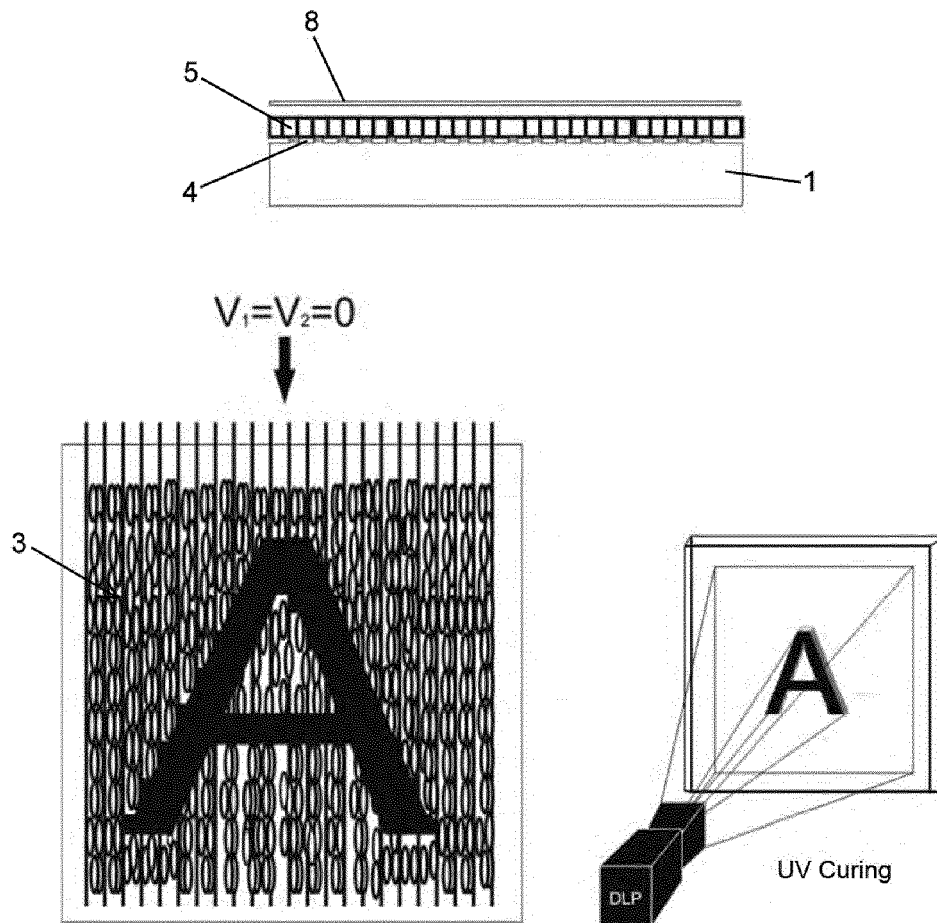


FIGURE 6

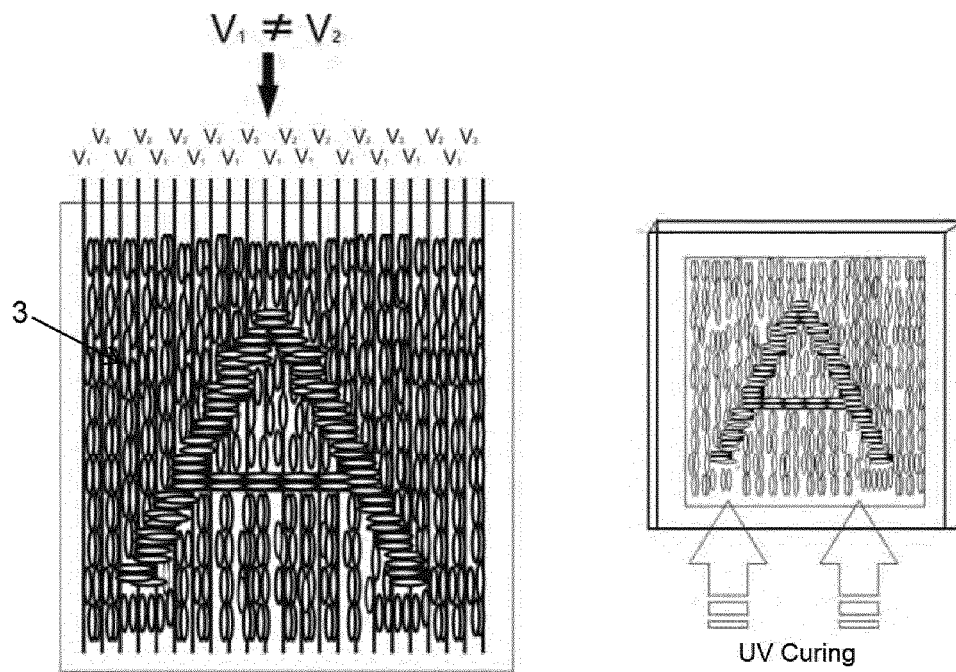


FIGURE 7

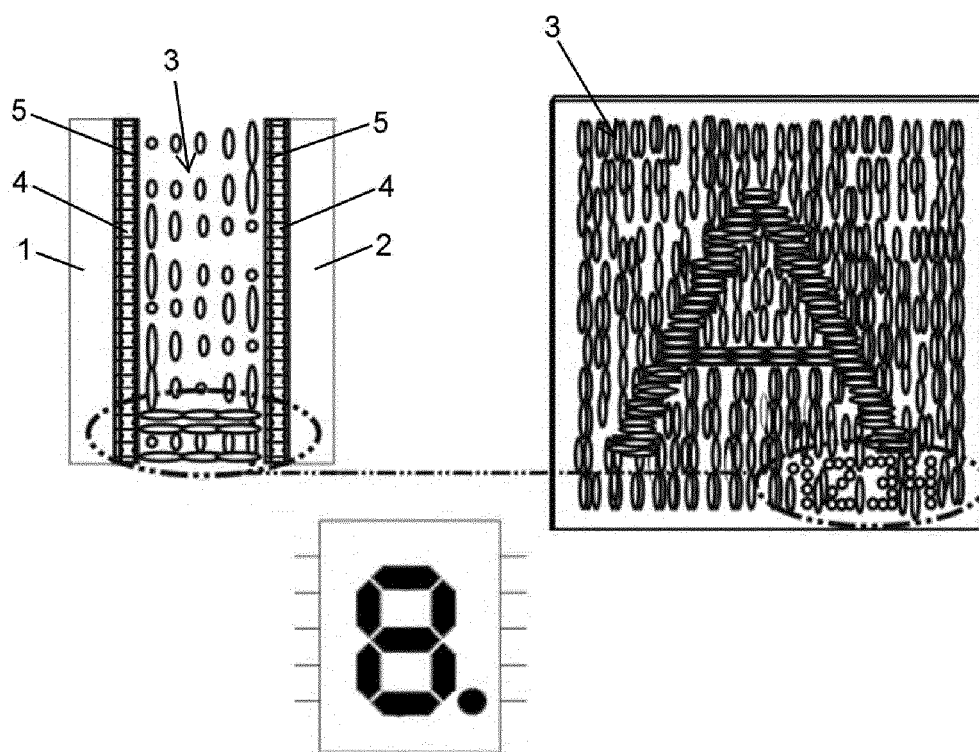


FIGURE 8

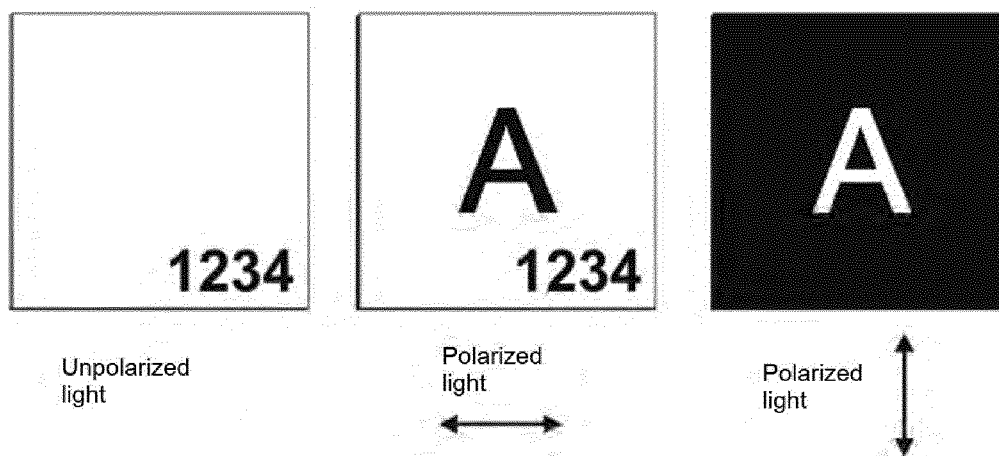


FIGURE 9

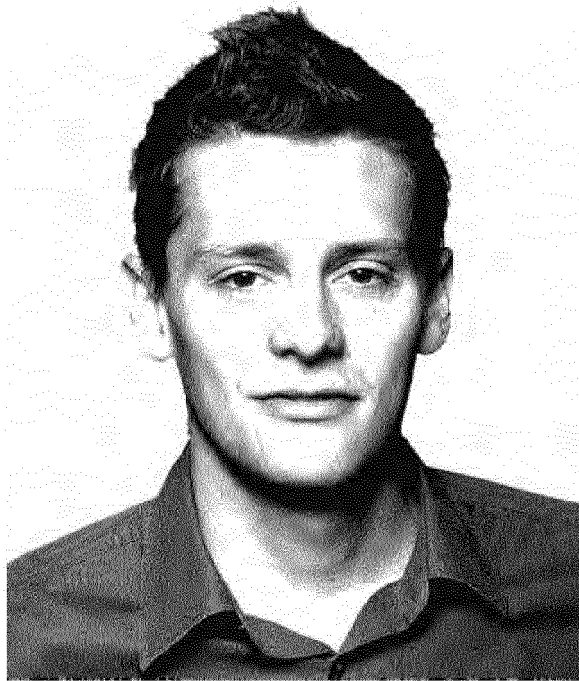


FIGURE 10

INTERNATIONAL SEARCH REPORT

International application No.

PCT/ES2017/070726

A. CLASSIFICATION OF SUBJECT MATTER

G07D7/12 (2016.01)**B41M3/14** (2006.01)

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G07D, B41M, G06K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPODOC, INVENES, WPI, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	ES 2337010 A1 (UNIVERSIDAD POLITÉCNICA DE MADRID) 19/04/2010, abstract; page 2, lines 7-10; page 3, line 3 - page 4, line 21; page 4, lines 41-51; page 5, lines 7-18; figures.	1-12, 14
A	WO 2017/060544 A1 (UNIVERSIDAD POLITÉCNICA DE MADRID) 13/04/2017, abstract; page 1, lines 6-11; page 4, line 13 - page 6, line 19; page 7, lines 5-9; page 8, line 3 - page 9, line 29; page 10, lines 13-25; page 11, lines 9-13; page 12, lines 7-10; page 12, line 30 - page 14, line 5; page 16, line 4 - page 17, line 8; figures.	1-10, 13, 14

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

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"&" document member of the same patent family

Date of the actual completion of the international search

24/07/2018

Date of mailing of the international search report

(25/07/2018)

Name and mailing address of the ISA/

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/ES2017/070726

C (continuation).	DOCUMENTS CONSIDERED TO BE RELEVANT	
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A	US 5602661 A (SCHADT, M. ET AL.) 11/02/1997, abstract; column 1, lines 3-20; column 1, line 47 - column 2, line 20; column 3, line 42 - column 5, line 38; figures.	1-3, 5-8, 10, 14
A	EP 2259102 A1 (FUJIFILM CORP.) 08/12/2010, abstract; paragraphs [0004]-[0008], [0010], [0076]-[0083]; figures.	1, 10-12, 14

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/ES2017/070726

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