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(54) **A METHOD OF PRODUCTION OF A CARBONIZABLE POLYMER SUBSTRATE WITH A TACTILE MARKING IN FORM OF A RELIEF AND A SECURED POLYMER SUBSTRATE OBTAINED BY THIS METHOD**

(57) The present invention relates to a method for the manufacture a carbonizable polymeric substrate having a tactile relief marking with an emboss effect, in particular a data carrier substrate for documents with security features, the method comprising securing the carbonizable polymeric substrate of step b) by applying to the substrate a marking in the form of a relief with an

emboss effect, by spot irradiation of a carbonizable polymer substrate by means of a computer-controlled RGB laser, the beam of which modifies the carbonizable polymer substrates at least in a part of the area, preferably over the entire area, the markings being obtained in the form of a relief with an emboss effect are obtained by creating punctual protrusions.

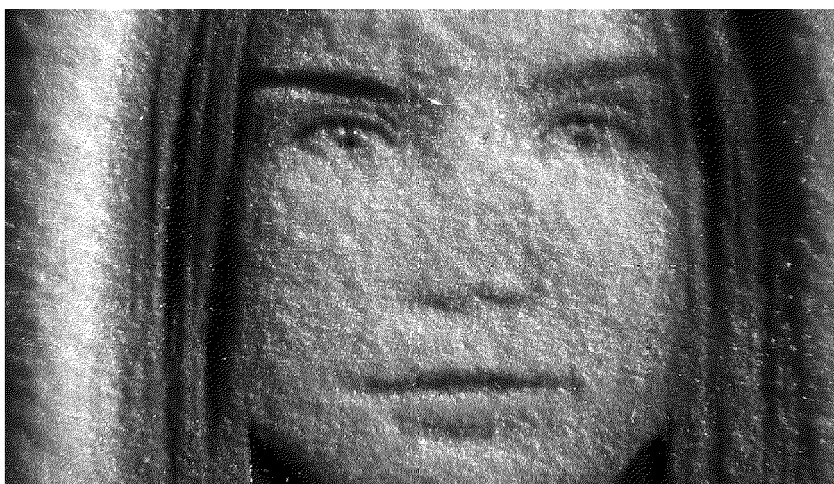


Fig. 8

Description

[0001] The present invention relates to a method for the manufacture of a carbonizable polymer substrate with a tactile relief marking with an emboss effect, in particular a data carrier substrate for documents with security features, and a secured polymer substrate manufactured by this method having a tactile relief marking with an emboss effect.

Prior art

[0002] Secured documents, such as securities or identification documents confirming the existence of certain rights, legal relationships, or legal events expressed on specific information carriers, are currently an indispensable element of life in developed countries. Their importance is constantly increasing, as such documents find many applications and their number is constantly growing.

[0003] Moreover, despite the constant digitization of all spheres of human life, it still seems impossible without physical documents confirming the identity of its holder, especially in such important situations as opening a bank account enabling the use of convenient digitized payments, receiving important correspondence, legal-administrative proceedings, or moving, especially outside the country.

[0004] Many of the identification or security documents comprise a polymer substrate, a polycarbonate in particular, with at least one security marking selected from a wide range of available security features. To prevent counterfeiting, such documents, for example identification documents such as an identity card, driver's license or passport, are often provided with sufficient first-level security features visible to the unaided eye to allow for a quick initial visual verification of the document's authenticity. However, to increase the security of the circulation of such documents, several security features are generally used, such as guilloches, holograms, etc. However, in the field of security, it is important to always stay one step ahead of counterfeiters, in particular due to known and recognizable but constantly improved security features.

[0005] For purposes of this application, the term "identity document" should be broadly defined to include credit cards, bank cards, phone cards, passports, driver's licenses, network access cards, employee ID cards, debit cards, security cards, visas, immigration records, national ID cards, citizenship cards, social security cards, security badges, certificates, ID cards or identification documents, voter registration cards, police ID cards, border crossing cards, security clearance legal instruments, badges and cards, gun licenses, gift vouchers, membership cards or badges etc.

[0006] Many types of identity documents, such as driving licences, ID cards, or bank or access cards, contain vital information that relates to the identity of the holder.

Examples of such information include, for example, name, address, date of birth, signature and photograph; cards or documents may additionally contain other variable data (i.e. personal data for a specific card or document) and fixed data (i.e. data common to a large number of cards). In addition, such documents can be provided with other elements, including those containing hidden information, and thus constituting second-level security, such as a photographic image or a bar code. Such features may be applied by a variety of technologies including, but not limited to, printing using technologies such as dye diffusion thermal transfer (D2T2), inkjet printing, thermal transfer, laser xerography, offset printing, gravure printing, and indigo printing. However, these printing techniques are not the only means of applying markings and information to data carriers for identity documents. Currently, laser beams are commonly used for this purpose, in particular for marking, writing, barcoding and engraving many hard substrate materials, including plastic substrates. Lasers are used to create markings such as bar codes, date codes, part numbers, lot codes and company logos. It should be noted that laser engraving or marking offers a wide variety of surface modification options, including recording or engraving the surface of a document with identification marks, characters, text, tactile markings, patterns and photographs.

[0007] A particularly useful type of security features are laser engraved markings on plastic laminates or cards. In the laser engraving process, data is recorded by blackening (charring) such laser-sensitive and laser-markable laminated films, such as, for example, polyvinyl chloride (PVC) or polycarbonate (PC) films. In addition, the laser engraving effect can be varied depending on the engraving depth. In the case of flat engraving, blackening is achieved only in the region of a certain layer. Another option is relief laser engraving for tactile marking.

[0008] Depending on the need, markings on the thermoplastic material can be manufactured by several different mechanisms or combinations of engraving or laser marking mechanisms, depending on the specific material used, including, in particular, the additives used, the nature of any coloured pigments introduced into the thermoplastic material, or the laser energy characteristics to produce a variety of markings including light, dark or colour markings. Polymers that have no or low tendency to carbonize, such as polyolefins and high-density polyethylene (HDPE), can produce light markings due to foaming of the resin by the heat generated by the laser energy. Other polymers such as polycarbonate (PC), ABS or polystyrene, show a much greater tendency to carbonization than foaming, and thus the markings applied are dark markings.

[0009] It is also known in the art to create a mark by applying an image of individual punctual elements, commonly referred to as pixels, to a substrate.

[0010] The document EP2851207B1 teaches, inter alia, of a document with a security feature on a polycarbonate substrate, the security feature being a laser-pro-

duced mark, for example with a beam length of 532 nm, consisting of a plurality of "pixels" forming such a mark. The carbon particles of the polycarbonate substrate undergo a reaction under the influence of the laser, resulting in black pixels in places exposed to laser pulses. Depending on the number of laser pulses used, the size and shape of the resulting pixels may change.

[0011] On the other hand, the publication US7789311B2 discloses applying markings constituting security features through creating an image by forming pixels using an engraving and/or laser marking technique. By forming pixels using this method of laser engraving, it is possible to precisely control the colour saturation of the applied pixels with high accuracy. As indicated in the description, laser darkening or "whitening" can be done with a laser even on a finished, laminated identity document.

[0012] Similarly, US 2009/0127844 A1 discloses a security feature for secured papers, security documents and the like comprising a laser markable transparent or translucent layer in which, by the action of laser radiation, visually perceptible identifiers in the form of patterns, letters, numbers and/or pictures are introduced.

[0013] A similar solution is disclosed in the international application publication WO 2013/093230 concerning a method of creating colour laser images. The latent image, consisting of coloured sub-pixels and non-coloured areas, is adjusted using a laser beam which, in a laser-markable layer beneath the coloured sub-pixels and non-coloured areas, modifies the selected areas to produce the colour laser image.

[0014] The patent document EP2918424B1 discloses a security document comprising printed data and a plurality of spaced microscopic bulges formed in a layer of laser markable material, at least some of the spaced microscopic bulges and printed data being mutually overlapped and at least some of the spaced microscopic bulges do not overlap the printed data, and the spaced microscopic bumps are arranged to form an image,

wherein the spaced microscopic bumps that overlap the printed data are different in size from the spaced microscopic bumps that do not overlap the printed data,

wherein the microscopic protrusions that superimpose the printed data are non-uniform. In one embodiment, the microscopic bulges include tactile bulges.

[0015] Other devices known in the art for laser marking and/or engraving and useful for performing such marking and/or engraving on various substrates are disclosed, inter alia, in the following patent publications: US5298922, US5294774, US5215864 and US4732410. In addition, it is also known to use lasers to apply various information to security documents. Examples of such applications are disclosed in the following patent specifications: US4816372, US4894110, US5005872,

US5977514 and US6179338.

[0016] None of the known documents, however, disclose a solution using laser engraving to create on easily carbonizable polymeric substrates, in particular polycarbonate substrates, tactile markings of variable colour and variable colour saturation and intensity, and at the same time, a high degree of detail and accuracy of details of the manufactured marking in the emboss form, wherein the bright colour corresponds to the emerging elements with the greatest convexity and the easiest to feel in touch.

[0017] The publication "Incubation studies and the threshold for surface damage and cavity formation in the processing of polycarbonate by Nd:YAG laser", by Singh et al., Optics and Laser Technology 108 (2018) 592-601, reports creating small protrusions in the place of impact on the PC surface with a laser. The mechanism of formation of the laser-induced PC bubbles on the surface seems to be laser-induced chemical dissociation of polymer bonds by means of irradiation, which may be related to the glass-rubber phase transition of the laser-heated polymer material. Due to local photothermal heating, the PC particles expand on the outer surface, revealing themselves when irradiated with a laser pulse. The resulting protrusions are dome-shaped due to the surface tension of the laser-heated plastic polymer after reaching the glass transition temperature. However, as indicated in the publication, the resulting protrusions do not reach the size desired for tactile markings, and with prolonged heating or increasing the laser power, they break, creating a depression in the surface of the PC in the place of a protrusion.

[0018] The present inventors have surprisingly found that, using standard RGB lasers, it is possible to obtain a high-quality image, in particular a bright-coloured tactile text, on easily carbonizable substrates, such as, in particular, polycarbonate (PC) substrates, which can be a tactile marking constituting a security feature of the document. In the method proposed by the inventors, only a slight blackening of the laser-treated material is observed, and the tactile, laser-engraved convex pixels retain a bright colour, in contrast to the effect observed in the prior art solutions, where the engraved image is black.

[0019] In the structure of the PC card, standard markings were applied, such as, for example, markings in the form of a text analogous to dark markings applied as standard by laser engraving (for example, in a Polish identity card or a German driving license). In the case of standard printing, vector graphics, e.g. a text, the best effects (white) were obtained when a blue laser was used for marking. In the case of a marking in the form of complex raster graphics (i.e. grey-scale marking), the best visual effects were obtained using a green laser for engraving. This is most likely due to the specificity of raster graphics, in which a better effect is finally observed in the combination of tactile marking with a slight, delicate darkening of some grey levels of the convex bright marking. Such a result was observed in the case of the green

laser with the highest power among the tested RGB lasers. The present inventors have demonstrated that laser marking of bright tactile markings, also referred to as "pop-up" marking, requires more energy than classical laser marking applied on or in laser markable layers.

[0020] However, the resulting marking provides a much higher degree of security provided by the marking obtained by the method of the present invention. When markings are applied to a polymer substrate by the method according to the invention, there is no possibility of introducing any additional information in the area of the applied marking. For example, in the case of a marking reflecting the photograph of the holder of the document, it is not possible to modify the applied image by changing the applied elements or adding new ones (e.g. increasing the amount of hair, introducing characteristic elements such as moustache, glasses, etc.). The marking applied by the present method is applied in the volume of the substrate to be marked by laser treatment and it is an integral part of such substrate. Thus, it is a marking that is difficult to remove without interfering with the substrate itself. What's more, due to the very precise reproduction of individual image elements in the applied marking, provided by creating an image by bulges applied to a substrate of a different colour from very dark to bright, created in the laser processing process, where the height and colour of the protrusions are strictly defined by laser power with remaining parameters constant, any interference in the applied marking, for example in the reproduced photograph, which was to cause its correction, would have to be associated with a change in the colour, i.e. the height of the applied protrusion, which is impossible on a previously modified surface. Any additional interference in the structure of the applied marking results in its complete destruction. Thus, a change requiring an alteration in the colour of specific areas of the modified substrate, e.g. changing the reproduction of a photograph by correcting cheekbones, nose shape or even skin colour, is impossible.

[0021] The present invention provides a method for the manufacture of a tactile relief marking with an emboss effect on a carbonizable polymer substrate, in particular a data carrier substrate for documents with security features, in particular security documents with security features, the method comprising the step of:

- protecting the polymeric substrate undergoing carbonization by applying a marking to the substrate in the form of a relief with an emboss effect by spot irradiation of the polymer substrate undergoing carbonization by means of a computer-controlled RGB or IR laser, preferably RGB, the beam of which modifies the polymeric substrates undergoing carbonization at least in part of the area, preferably, over the entire area, the relief markings with an emboss effect being obtained by creating punctual protrusions, each protrusion corresponding to a single pixel from a two-dimensional array mapped on the sub-

strate as a graphical marking of an image defined in a source code graphic file describing the applied relief marking with an emboss effect, and wherein the distance between individual protrusions of the marked graphic image, defined as the centre of a circle describing the base of the protrusion on the plane to which it is applied, which centre corresponds to the centre of a circle describing a single pixel in the bitmap of the applied image and defines the location of the centre of the laser beam used for applying a protrusion to the surface, is at least equal to the radius of a single effective laser spot and is not greater than the radius of a single effective laser spot, wherein a single protrusion corresponds to a single pixel in the bitmap describing the applied marking,

and the power of the computer-controlled RGB or IR laser is variable depending on the desired colour and height of the relief, and does not exceed the maximum laser power at which the substrate does not degrade.

[0022] In a preferred embodiment, the method of the present invention further comprises at least one, more preferably all, most preferably all of the following steps carried out in the order listed below:

- transforming the source image corresponding to the marking applied to the carbonizable polymer substrate in the form of a relief with an emboss effect, in which step, after defining the graphic image to be ultimately applied to the carbonizable polymer substrate in the form of a relief, a set of input data defining the desired image constituting the markup as raster graphics in the form of a two-dimensional array of pixels is determined, preferably by means of a computer configured to design graphic images, and then, such determined input data is converted by a computer configured to perform such conversion into a coded graphic file of a source image record being a bitmap describing the marking to be applied;
- providing a carbonizable polymer substrate;
- adjusting the maximum laser power possible to be used for modifying the substrate without degrading it and determining the grey scale obtained in the range defined by such maximum laser power used for applying the laser marking; and the power of the laser controlled by means of a computer configured for this purpose, used for applying the relief marking with an emboss effect to the substrate, is variable in the range from 0 to 100 % of the maximum laser power determined in the step of adjusting the maximum laser power possible to be used for modifying the substrate depending on the desired colour, as defined in the bitmap, of applied protrusion defined by a single pixel, where the lowest laser power corresponds to applying a protrusion with the darkest colour, and the maximum laser power of 100 % ensures applying a protrusion with the brightest colour,

wherein the height of a single protrusion is directly proportional to the laser beam power used to create a protrusion that creates a tactile, raised marking on the surface of the substrate, which is different in colour from the non-laser-processed area and where the highest protrusions give the marking a bright colour, forming a grey-scale marking.

[0023] It should be emphasized that in this specification the term relief corresponds to any raised, tactile structure constituting the security marking of a document, which can be perceived in particular under angle lighting. On the other hand, the term "relief with an emboss effect" refers to such reliefs in which the protrusions differ in height and colour, providing the impression of depth of the document security marking also in transmitted light.

[0024] The maximum laser power that can be used for modifying the substrate without its degradation and determining the grey scale obtained in the range defined by such a maximum power of the laser used to apply the marking can be determined in any way, for example, by gradually increasing the laser power until, instead of the formation of protrusions, the destruction of the substrate by burning is observed. The maximum laser power is considered to be the laser power at which protrusions of the maximum achievable height and brightness are formed in a repeatable manner. Based on the difference in colour of the highest protrusion and the surface of the modified substrate not subjected to laser treatment, the grey scale that can be achieved with the use of a specific laser operating at a specific frequency is determined, in which the marking will be applied to the substrate.

[0025] Preferably, the power of the laser used to apply the relief marking with an emboss effect to the substrate is variable in the range from the minimum laser power to the maximum laser power at which there is no degradation of the substrate, in particular burn-through of the substrate, defined as 100 % of the maximum laser power, more preferably from 30 % of maximum laser power to 100 % of maximum laser power, more preferably 20 % of maximum laser power to 100 % of maximum laser power, most preferably 20 % of maximum laser power to 100 % of maximum laser power.

[0026] In one of the preferred embodiments of the invention, the maximum power of the laser used to apply the relief marking with an emboss effect to the substrate is in the range of 1000.00 mW to 8000.00 mW, more preferably in the range of 2500.00 mW to 5000.00 mW, most preferably is 3500.00 mW.

[0027] Preferably, the frequency of the laser used to apply the relief marking with an emboss effect to the substrate does not exceed 100.00 kHz, more preferably does not exceed 50 kHz, most preferably is 50 kHz.

[0028] In preferred embodiments of the method according to the invention, the relief marking with an emboss effect is applied over an area of no more than 12 by 12 mm, preferably no more than 10 by 10 mm.

[0029] Preferably, the laser used to apply the relief

marking with an emboss effect to the substrate is a green laser or a blue laser, preferably a green laser with a laser beam wavelength of 532 nm, or a blue laser.

[0030] In preferred embodiments of the method according to the invention, the distance between the individual protrusions of the graphic image applied as a marking is equal to at least 0.4 of the radius of a single effective laser spot and is smaller than the radius of a single effective laser spot, preferably it is equal to at least half of the radius of a single effective laser spot and is less than 0.6 of the radius of a single effective laser spot.

[0031] The preferred substrate provided in the method of the invention in step b) to which the marking is applied is a polycarbonate or polyvinyl chloride substrate or a substrate coated with an additional polycarbonate or polyvinyl chloride protective layer, preferably a transparent polycarbonate or polyvinyl chloride protective layer. More preferably, the substrate is a polycarbonate substrate or a substrate coated with a transparent polycarbonate film.

[0032] The present invention also relates to a secured polymeric substrate bearing a tactile marking in the form of a relief with an emboss effect, in particular constituting a data carrier for documents with security features, especially security documents with security features, manufactured by the method of the present invention.

[0033] A preferred tactile marking in the form of a relief with an emboss effect as a security feature is a marking containing personal data and/or individualizing markings. More preferably, the tactile marking in the form of a relief with an emboss effect is a representation of a photograph, preferably a photograph of a document holder, such as an ID card, driver's license, admission card.

[0034] The present invention also provides a secured substrate for a document, which is a multi-layer document wherein at least the outer layer is a layer of a carbonizable material or a layer coated with a film of a carbonizable material, provided with a tactile marking in the form of a relief with an emboss effect manufactured by a method as set forth in any one of claims 1-9.

[0035] The present inventors surprisingly found out that due to the use of RGB or IR lasers, in particular commonly available RGB lasers, by controlling the power level of such a laser, in a single-stage method of modifying the polymer surface susceptible to carbonization, it is possible to obtain very precise marking of embossed character, containing many details and constituting an integral whole with the base, wherein this method additionally enables a significant improvement of the security level of the document provided with such protection due to the possibility of easy personalization of the marking obtained by the method according to the invention and the impossibility of any interference in the area on which the marking has been applied.

[0036] The present invention aims to satisfy the need to provide a relatively inexpensive and easily recognizable means for authenticating security documents on a polymer substrate, characterized by an increased degree of security, enabling easy personalization of documents

provided with such security features in a simple, one-step process.

[0037] It should be emphasized that applying the marking in the form of a relief with an emboss effect using the method according to the invention is not only extremely simple and effective, but also does not lead to any modification, in particular damage, to the non-laser-treated surface areas of the security document. Thus, it is not only possible, but also in no way limited, to apply to the polymer surface of such a document, outside the area of the applied marking, other security features different from the marking obtained by the method according to the invention.

[0038] In addition, it should be emphasized that due to the simplicity of the proposed solution, a security feature in the form of a relief with an emboss effect can be placed on the finished product, which in turn allows for the use of both centralized and decentralized personalization. Thus, the present invention provides an effective, accessible and inexpensive security feature that is easy to process and incorporate along with other security features.

[0039] As used herein, the terms "light" and "radiation" may be used interchangeably and mean a flux of emitted particles, for example emitted by a laser.

[0040] It is to be understood that as used herein, the terms "hue" and "shade" and "colour" are used interchangeably herein to denote different lengths of reflected light as perceived by an observer. In summary, with regard to the phenomenon of colour perception, it should be assumed that two different shades/hues/colours are different from each other because light is emitted or absorbed by one shade at a specific wavelength that is different from the wavelength of the other shade. The grey-scale colours of the monochrome mode in the bitmap describing the applied marking include, apart from the extreme black and white colours, a whole range of intermediate colours (greys) with various levels of brightness. As used herein, intermediate colours that differ in brightness are considered to be different colours.

[0041] In accordance with the present invention, the term "tone" is to be understood as referring to the different intensity of the same colour. In summary, regarding the phenomenon of perceiving a change in tone, it must be assumed that two different tones are different from each other because the light is emitted or absorbed with different intensities.

[0042] As used herein, the term "substrate" should be interpreted broadly. Thus, for example, the substrate may be any single-layer substrate as well as a multi-layer laminate. The substrate can be both a prefabricated product for the production of the target product, such as a single layer of a polymeric substrate, which, after marking, provides a protected polymeric substrate for further use, including incorporation into a multilayer system, in particular a permanently bonded multilayer substrate. The substrate may also be a final product, such as an identification document containing at least one marking intended to convey information, such as, for example, an identity

card or a driving license.

[0043] As used herein, whenever a "picture" or "marking" is referred to, it is generally understood to mean any visually and/or machine readable pattern, often comprising specific information, that can be captured by an observer in a normal, single act of cognition. In particular, such patterns may be simple geometric patterns or textual and numerical information. Such images or markings include realistic motifs as well as abstract motifs. Examples of realistic motifs are, in particular, photos, portraits, landscape, plant or animal motifs. Realistic motifs can also be images of coats of arms, buildings, flags. Abstract motifs include all other graphically presentable markings, including in particular those that are specific patterns, signs, including trademarks, or codes. Other specific examples of abstract motifs are text or single letters or numbers. However, the list of the above-indicated images is not exhaustive as such images or markings within the security feature can be laser engraved into any shape.

[0044] The present invention is illustrated in the drawings, in which:

Fig. 1 shows a tactile marking obtained on a transparent card substrate.

Fig. 2 shows the tactile marking obtained on a substrate in the form of an initial (basic) card (left, Fig. 2 a)) and a card with a 100 μm overlay of a transparent film (right, Fig. 2 b)).

Fig. 3 shows the tactile marking obtained on an opaque, "white", non-transparent overlay film coated card.

Fig. 4 shows the tactile marking obtained on the initial card substrate at a laser frequency of 20 kHz.

Fig. 5 shows the tactile marking in the form of a raster graphics obtained on an ID card substrate, also referred to as the "base material", with a low laser power drop range of 100 % - 30 % (left) and a maximum laser power drop range of 100 % - 0 % (right).

Fig. 6 shows the tactile marking in the form of a raster graphics as shown in Fig. 5 on the right under different illuminations, a) right-hand illumination, b) overhead illumination and c) transmitted spot illumination.

Fig. 7 shows the tactile marking in the form of a raster graphic as shown in Fig. 6 c), magnified.

Fig. 8 shows the tactile marking in the form of a raster graphics obtained on an ID card substrate, also referred to as the "base material", with an average range of 100 %-20 % laser power drop in right-hand illumination, shown under magnification.

Fig. 9 presents the results of the measurement of the height of the protrusions of the tactile marking in the form of a raster graphics: a) on the left, the measurement for the highest protrusion (bright elements) in relation to the card surface and b) on the right, the measurement of the highest protrusion (dark elements) in relation to the white core of the card, which is a multi-layer arrangement of white films, against

the surface of the card.

Fig. 10 shows a comparison of exemplary markings in the form of a representation on the surface of a photograph personalizing the document depending on the parameters of the laser marking process, in particular the parameters of the laser setting.

Fig. 11 shows a comparison of exemplary markings in the form of a representation on the surface of a photograph personalizing the document depending on the parameters of the laser marking process for the blue laser (constant laser wavelength).

[0045] The attached figure shows the effects of laser marking of an easily carbonizable polymer substrate with a tactile marking with light and dark shades. The bright protrusion effect was obtained due to the appropriate selection of laser parameters, sufficiently high power combined with the appropriate density of pixels.

[0046] The basic material for the tests was a PC card made in a symmetrical structure, consisting of transparent engraving films constituting outer layers with a thickness of 200 μm , and internal films, which comprised white polycarbonate films with a thickness of 400 μm .

[0047] Markings constituting personalizing security features were applied using a green laser (Coherent Matrix, 532 nm wavelength). The application of the marking was preceded by designing, using a computer configured to design graphic images, a source image corresponding to the marking applied to the polymer substrate undergoing carbonization in the form of a relief with an emboss effect. Then, a set of input data defining the desired image constituting the applied marking as a raster graphic in the form of a two-dimensional array (matrix) of pixels was determined by computer, and then such designed input data was transformed by means of a computer configured to perform such a transformation into a code graphic file constituting a bitmap describing the mark to be applied. The laser was computer controlled by adjusting the laser parameters based on the laser configuration data for each protrusion corresponding to a bitmap pixel.

[0048] In the systems discussed below, optimal laser parameters were used to guarantee the best quality of the marking reproduced on the polymer substrate, in particular the image such as a photograph, using a laser with a wavelength of 532 nm, maximum power of 3.5 W. This power corresponded to 100 % of the laser power at the frequency of laser pulses 50 kHz. The spacing between pixels (adjacent dots - laser pulses) was set to 14 μm . This arrangement ensured that with an effective laser spot size of about 50 μm , adjacent points partially overlap. With the modification of the substrate designed in this way, although the PC substrate is a polymer substrate that is easily carbonized, bright or at least brightened areas with convex, tactile markings were obtained. The protrusions on the substrate, which was a polymer card made of polycarbonate, are formed as a result of foaming of the material under the influence of laser treatment.

[0049] In order to obtain raster graphics (with a variable grey scale), it is necessary to change the colour / tone of the colour of the protrusion created by the laser. In the case of classic personalization of polymeric substrates with a laser, by reducing the power of the laser used to apply the personalizing marking, a brighter colour and lower blackening of the substrate susceptible to carbonization are obtained. This translates into obtaining a grey-scale marking from black to white, and due to the carbonization process taking place at higher laser powers, the marking obtained is less diverse in terms of the maximum distance of each protrusion from the plane of the substrate on which it is applied.

[0050] In the method according to the invention, unlike the case of classic "jump" laser marking of the substrate, reducing the laser power leads to a higher blackening of the laser-marked area, while reducing the protrusion, until reaching a state in which no protrusion is obtained. The marking obtained in this way is tactile due to the protrusions located on at least part of the surface, providing the visual effect of embossing with a variable shade of grey. The lowest levels of the grey scale (i.e. representation of darker colours) correspond to places where the marking elements were applied using a laser operating in the low power range, in particular in the range of 0 - 30 %, in particular 0-20 % of the maximum laser power.

[0051] Completely different effects were obtained for other power parameters. When reducing the laser power to 20-30 % of the maximum laser power, and leaving the other parameters unchanged, we do not get the convex effect. The result is a classic grey-scale blackening.

[0052] Keeping the laser power unchanged and increasing the spacing between adjacent pixels, a darker marking was obtained, reproducing the photograph and constituting a personalizing security feature. For a better and more accurate assessment of the influence of pixel distance on the quality of the obtained marking, the distance between adjacent pixels was reduced. However, it was observed that the reduction of the distance between adjacent pixels above the value of 30 % of the average diameter of a single pixel, where the diameter of a pixel is the diameter of a circle describing a single pixel, constituting a segment connecting the most distant points on the surface of the circle and passing through its centre (which corresponds to the area of substrate modification under the influence of a single laser pulse), defects in the form of air bubbles are formed. At the same time, increasing the distance between adjacent pixels leads to a darker image. On the other hand, when the laser power was lowered, the number of defects was reduced, but then the height of individual protrusions was also decreased, which made the marking much less clear, the contours of applied individual elements were blurred and the marking became less tactile.

[0053] For the parameters of 100 % laser power used for application on the carbonizing polymer surface, and frequency of 50 kHz, and spacing between adjacent pixels

els of 12 μm in the area corresponding to the brightest colours, irregular defects were observed, which represented irregular foaming.

[0054] For the parameters of 100 % laser power used for application on the carbonizing polymer surface, and frequency of 50 kHz, and spacing between adjacent pixels of 16 μm , the area corresponding to the brightest colours is much darker, and with optimal parameters, guaranteeing the desired accuracy of reflecting the applied image, its depth and readability was observed while maintaining excellent palpability.

[0055] What's more, also when changing the laser power, a significant deterioration of the effects was obtained. The tests were performed for lower laser power amplitudes used for applying markings. For the parameters of the maximum laser power used for marking the substrate at the level of 75 % of the maximum laser power, frequency of 50 kHz, distance between adjacent pixels of 12 μm , the marking obtained as a reproduction of the photograph provided sufficient contrast between the individual elements of the marking and the visibility of minor differences in shades for the grey scale.

[0056] For the parameters of the maximum laser power used for marking the carbonizing polymer substrate at the level of 50 % of the laser power, frequency of 50 kHz, and the distance between adjacent pixels of 10 μm , darker areas reflecting bright colours were obtained. When the spacing between adjacent pixels was reduced to 8 μm , irregular defects appeared in areas corresponding to bright colours. When increasing the spacing between adjacent pixels to 14 μm , it was observed that the areas of "white protrusions" become darker than at the spacing between adjacent pixels of 10 μm , and thus the markings lose their embossed appearance. Selected results obtained for the initial card are shown in Fig. 1, where the frequency and maximum output power of the laser, the spacing between pixels and the change in laser power during applying the marking are indicated under the obtained images. In all Figures, unless expressly stated otherwise, a numerical value with the letter "k" corresponds to the applied laser frequency in kHz (as, for example, 50k represents a laser power of 50 kHz), a numerical value with the symbol "%" corresponds to the applied laser power (such as 100 %), the value ranges correspond to the changes in laser power in "%" that were used to apply the marking (such as 20-100), and the numerical value with the letter "u" corresponds to the distance in μm between adjacent pixels (like, for example, 14u).

[0057] The tests carried out were also repeated for a different structure of the polymer substrate undergoing carbonization, which was a transparent card made entirely of transparent PC films with a thickness of 800 μm . The effects obtained in the study are similar, and the slight differences observed result from the different characteristics of the transparent and non-transparent substrate. However, for the transparent card, the best results (closest to the optimal effect obtained on the initial card)

were obtained for slightly different parameters: 100 % of the laser power used for application to the carbonizing polymer surface, frequency of 50 kHz, spacing between adjacent pixels of 11 μm . For such a distance between adjacent pixels (optimal parameters for the initial card), the areas of white protrusions are slightly darker than in the case of a transparent card. Selected results, obtained for a card made of a white 400 μm core with two 200 μm transparent protecting "overlay" layers (referred to as the initial card, Fig. 2 a)), and for a card made of a white 400 μm core with one, transparent outer "overlay" layer with a thickness of 100 μm (Fig. 2 b)), is shown in Fig. 2, where under the obtained images the frequency and maximum output power of the laser, the spacing between pixels and the change of laser power during marking application is indicated.

[0058] For the parameters of 100 % laser power used for application to the carbonizable polymer surface, a frequency of 50 kHz, a distance between adjacent pixels of 12 μm , a personalizing marking was obtained, which was a mapped photograph, similar to that obtained with optimal parameters in the structure of the initial card. Slight differences, especially with regard to details, such as the amplitude of the height of the protrusions or shades (tones) of the grey scale, did not have a significant impact on the visual perception of the applied image. For the same parameters (optimal as indicated as optimal for the initial card), the reflection of the grey scale gave slightly different visual effects - the black areas are slightly brighter. However, the overall visual effect obtained was determined as favourable and corresponding to the embossed structure.

[0059] Another card that was subject to personalization was a card made of white film without an additional external transparent "overlay" film. In this case, effects similar to those obtained on cards with transparent film were not obtained. The obtained marking does not have the desired embossed character, is obscure and lacks depth. The image reflecting the photograph is free from the desired, tactile protrusions varied in terms of height, and in places where the laser power is high, we only get blackening. Moreover, when the energy of the laser beam used to modify the substrate was increased, a slight ablation of the material was observed with simultaneous local blackening of the substrate in the area of the laser beam action.

[0060] The initial card was also tested at a changed laser operating frequency of 20 kHz. Satisfactory results were also obtained for such a low frequency. For the parameters of 100 % laser power used for marking the carbonizing polymer surface, frequency of 20 kHz, the most favourable spacing between adjacent pixels was 11 μm . For other parameters, worse results were obtained, as was in the case of the higher laser frequency of 50 kHz. However, on reducing the distance between adjacent pixels to 10 μm , the colour and shape of the "white protrusions" was more favourable than when reducing the distance between adjacent pixels for a fre-

quency of 50 kHz. The colouring of the resulting image was also satisfactory.

[0061] It should be emphasized that on each occasion the process of applying the marking to the surface of the substrate, in particular the personalizing marking, such as a photograph, was carried out in the same way as in the case of classic modification of surfaces susceptible to laser marking.

[0062] Fig. 5 shows the pictures obtained with different steps of the laser power change. The photograph on the left (a) was obtained using grey scales, where the lowest laser power (dark colours) corresponds to the use of a laser beam with a power of 30 % of the maximum laser power of 100 %, which is the maximum laser power responsible for obtaining bright colours in the applied raster graphics. The image obtained in this way is convex, has the embossed character, and due to the use of a beam with maximum power that provides bright protrusions in the places of laser marking, bright "jump" marking is obtained. The photograph shown in Fig. 5 B) was taken in a similar way, based on the same source file, with the difference that the lowest laser power was 0. The marking obtained with such a large span in laser power from 0 - 100 % is characterized by even more visually favourable effect, with the high depth of the image obtained and the detail of the marking applied to the substrate. The marking representing an image obtained with a narrow laser power amplitude (30 - 100 %) is a grey-scale marking and with lower contrast than a marking obtained with a maximum laser power amplitude (0-100 %) contrast image, both in terms of colour/colour tone change differentiating the individual elements of the applied image, as well as the difference in the height of the obtained protrusions. Independently, the security feature obtained by controlling the laser power based on the negative of the photograph not only enables the personalization of the document marked with such a marking, but it is legible, suitable for perception with two independent sense organs - sight and touch, and impossible to remove from the document without destroying its structure, and thus significantly increases its safety.

[0063] The marking, obtained as described above with reference to Fig. 5 b), is shown in Fig. 6 in views for different lighting variants. Regardless of the angle of incidence of light revealing the marking, it has a clear embossed character, perfectly reflects fine details of the image applied on the basis of the source file, it is easily perceived with the naked eye, and at the same time it is perfectly tactile.

[0064] The high degree of accuracy of the marking detail mapping is visible in the magnification of the image in Fig. 7, applied to the substrate based on the negative of the image, in the right side illumination. This magnification shows a perfect reflection of protrusions obtained in the document personalization process proposed in the present method. The marking made in the original size, 10 mm high, reflects the details well enough to easily identify the person presented in the reproduced photo-

graph. It should be emphasized that the small size of the applied markings provides an excellent visual effect, which is related to a better ratio of the amplitude of the protrusions to the entire modified area. The photograph can be resize any arbitrary way. The height of the protrusions, i.e. the distance of the point on the protrusion surface that is maximally removed from the plane of the modified substrate, is at a constant level, for the given substrate parameters (its type) and the laser used for its modification (power, frequency) and the grid density of the applied pixels (where a single pixel in the source file corresponds a single protrusion on the surface of the modified substrate). Hence, with appropriate proportions of the height of the protrusions to the size of the photograph, it is possible to obtain very favourable effects at small sizes of the applied images. Particularly favourable effects and the quality of mapping the applied image were obtained with the size of the markings, height and width, within the range of 10 - 12 mm. Smaller sizes of markings, especially as complex as the image of the document holder's photograph on the surface, despite the excellent "emboss" effect, do not seem to constitute practical security features due to the small size and poor legibility of the marking representing the image of the photograph, perceived by the unaided eye of the observer. Sizes of the marking larger than 12 mm, and especially larger than 15 mm, in particular representing a photograph, also seem to be of much less practical use. Due to the high ratio of the height of the protrusions to the width / height of the applied marking, the embossing effect is visually less favourable.

[0065] As noted above, the protrusion height of the laser engraving is constant, regardless of the size of the graphics. Its height can be adjusted only with a laser power, but depending on the selection of this parameter, we also get a different colour shade (colour). The highest protrusions were obtained for a bright colour, and when the power was reduced, the protrusion was reduced, but also an increasingly darker colouration of the laser-modified area was observed. The heights of individual protrusions obtained in this method, measured in relation to the surface of the card, ranged from 0.15 - 0.2 mm in the highest spot and were observed as the brightest elements of the marking. Darker coloration was observed at lower laser powers, and the height of the protrusions corresponding to these areas ranged from 0.5 - 0.15 mm. Protrusion surfaces are formed as a result of foaming of the material, however, due to the overlapping of pixels in the source image, corresponding to the places of laser processing, the surface created with the same laser parameters is almost smooth, and the heights of the resulting protrusions differ slightly.

[0066] The markings were applied to the substrate using a laser with different parameters. The personalizing markings obtained are shown in Fig. 10, which shows a general view of the initial card (base material) with images constituting representation of a photograph, obtained for different settings of the green laser and different graph-

ical representations of the photograph. The best marking effects, enabling the use of the method for repeated personalization of a document with a high legibility marking, are provided by the use of raster graphics, with the best effects being obtained in the range of large differences in the laser power amplitude (g). When using other graphics presentation options, as in the case of creating a source file defining the applied markings using the Floyd-Steinberg algorithm (Fig. 10 m, n) or duotone photos (Fig. 10 i, p), no the desired effect is obtained and the resulting marking is illegible. Similarly, illegible marking is obtained when the pixel density is significantly increased so that the distance between adjacent pixels is less than the average radius of a single pixel, as air bubbles are formed in the graphics (Fig. 10 f).

[0067] The influence of the laser power on the marking obtained is shown in Fig. 11. A blue laser with a lower available maximum power than the green laser was used to apply the marking. As shown in Fig. 10, the obtained tactile personalization mark made with a lower power laser (Xiton Photonics Idol - C, 447 nm wavelength) does not provide such good results due to the reduced value of the laser power amplitude used for image application.

[0068] To sum up, as shown in the exemplary embodiments of the invention discussed above, the method proposed by the present inventors provides the possibility of full personalization of the applied marking functioning as a security feature, made with high precision and accuracy of reproduction, being a tactile marking, and at the same time having the embossed character. As shown, by using a high-power, variable-amplitude laser, it is possible to obtain security features which are highly detailed, easily recognizable to the naked eye, including personalization elements such as a reproduction of a photograph of the document's holder. Such protection is quick and easy to implement, it does not require any costly operations, and the protected polymer substrate obtained in accordance with the invention, provided with a marking acting as a security feature, is very durable and stable. Removing the marking requires degradation of the surface on which it is applied, and thus is tantamount to destruction of the security document bearing such a security feature. At the same time, due to the possibility of applying the markings with a laser controlled by a computer adapted for this purpose and using graphic files defining the form of the applied markings as source files, it is possible to personalize the marked documents with more complex images, including images reflecting the image of the holder of a document secured by such a marking.

[0069] Thus, the solution provided by the present inventors, although relatively easy and inexpensive to implement, is characterized by a very universal character and many different applications, including in particular for the manufacture of personalization elements in the area of the security feature of security documents on carbonizable polymer substrates, especially PC substrates.

[0070] Although the present invention has been de-

scribed with reference to specific preferred embodiments only, it will be apparent to those skilled in the art that various modifications, changes, omissions, and substitutions may be made in the described embodiments without departing from the common technical idea defined in the specification of the claimed solutions comprising the subject-matter of the patent claims defining the scope of patent protection.

Claims

1. A method for the manufacture a carbonizable polymer substrate with a tactile relief marking with an emboss effect, in particular a data carrier substrate for documents with security features, in particular security documents with security features, the method comprising the step:

- protecting the polymeric substrate undergoing carbonization by applying a marking to the substrate in the form of a relief with an emboss effect by spot irradiation of the polymer substrate undergoing carbonization by means of a computer-controlled RGB or IR laser, preferably RGB, the beam of which modifies the polymeric substrates undergoing carbonization at least in part of the area, preferably, over the entire area, the relief marking with an emboss effect being obtained by creating punctual protrusions, each protrusion corresponding to a single pixel from a two-dimensional array mapped on the substrate as a graphical marking of an image defined in a source code graphic file describing the applied relief marking with an emboss effect,

and wherein the distance between individual protrusions of the marked graphic image, defined as the centre of a circle describing the base of the protrusion on the plane to which it is applied, which centre corresponds to the centre of a circle describing a single pixel in the bitmap of the applied image and defines the location of the centre of the laser beam used for applying a protrusion to the surface, is at least equal to the radius of a single effective laser spot and is not greater than the radius of a single effective laser spot, where a single protrusion corresponds to a single pixel in the bitmap describing the marking to be applied, and the power of the computer-controlled RGB or IR laser is variable depending on the desired colour and height of the relief, and does not exceed the maximum laser power at which the substrate does not degrade.

2. The method according to claim 1 or 2, further comprising at least one, preferably all, more preferably all, in the order listed, of the following steps:

- transforming the source image corresponding to the marking applied to the carbonizable polymer substrate in the form of a relief with an emboss effect, in which step, after defining the graphic image to be ultimately applied to the carbonizable polymer substrate in the form of a relief, a set of input data defining the desired image constituting the marking to be applied as raster graphics in the form of a two-dimensional array of pixels is determined, preferably by means of a computer configured to design graphic images, and then, such determined input data is converted by a computer configured to perform such conversion into a coded graphic file of a source image record being a bitmap describing the marking to be applied;

- providing a carbonizable polymer substrate;

- adjusting the maximum laser power possible to be used for modifying the substrate without degrading it and determining the grey scale obtained in the range defined by such maximum laser power used for applying the laser mark;

and the power of the laser controlled by means of a computer configured for this purpose, used for applying the relief marking with an emboss effect to the substrate, is variable in the range from 0 to 100 % of the maximum laser power determined in the step of adjusting the maximum laser power possible to be used for modifying the substrate depending on the desired colour, as defined in the bitmap, of applied protrusion defined by a single pixel, where the lowest laser power corresponds to applying a protrusion with the darkest colour, and the maximum laser power of 100 % ensures applying a protrusion with the brightest colour, wherein the height of a single protrusion is directly proportional to the laser beam power used to create a relief that creates a tactile, raised marking on the surface of the substrate, which is different in colour from the non-laser-treated area and where the highest protrusions give the marking a bright colour, forming a grey-scale marking.

3. The method according to claim 2, **characterized in that** the power of the laser used for applying the relief marking with an emboss effect to the substrate in step d) varies from 30 % of the maximum laser power to 100 % of the maximum laser power, preferably from 20 % of the maximum laser power to 100 % of the maximum laser power, most preferably from 20 % of the maximum laser power to 100 % of the maximum laser power.

4. The method according to any one of claims 1 to 3, **characterized in that** the maximum power of the laser used for applying the relief marking with an emboss effect to the substrate in step d) is in the range of 1000.00 mW to 8000.00 mW, preferably in the range of 2500.00 mW to 5000.00 mW, most preferably is 3500.00 mW.

5. The method according to any one of claims 1 to 4, **characterized in that** the frequency of the laser used for applying the relief marking with an emboss effect to the substrate in step d) does not exceed 100.00 kHz, preferably does not exceed 50 kHz, most preferably is 50 kHz.

6. The method according to any one of claims 1 to 5, **characterized in that** the relief marking with an emboss effect is applied over an area of not more than 12 by 12 mm, preferably not more than 10 by 10 mm.

7. The method according to any one of claims 1 to 6, **characterized in that** the laser used for applying the relief marking with an emboss effect to the substrate in step d) is a green laser or a blue laser, preferably a green laser with a wavelength of the emitted beam of 532 nm or a blue laser with a wavelength of the emitted beam of 447 nm.

8. The method according to any one of claims 1 to 7, **characterized in that** the distance between the individual protrusions of the graphic image marking is at least 0.4 of the radius of a single effective laser spot and is smaller than the radius of a single effective laser spot, preferably it is at least half the radius of a single effective laser spot and is less than 0.6 radius of a single effective laser spot.

9. The method according to any one of claims 1 to 8, **characterized in that** the substrate on which the marking is applied is a polycarbonate or polyvinyl chloride substrate, or a substrate coated with an additional protective layer of polycarbonate or polyvinyl chloride, preferably an additional transparent protective layer of polycarbonate or polyvinyl chloride.

10. The method according to claim 9, **characterized in that** the substrate is a polycarbonate substrate or a substrate coated with a transparent polycarbonate film.

11. A secured polymer substrate bearing a tactile relief marking with an emboss effect, in particular comprising a data carrier for documents with security features, in particular security documents with security features, obtained by a method as defined in any one of claims 1-9.

12. The secured polymer substrate according to claim

11, **characterized in that** the tactile relief marking with an emboss effect is a marking containing personal data and/or individualizing markings.

13. The secured polymer substrate as claimed in claim 12, **characterized in that** the tactile marking in the form of a relief with an emboss effect is a reproduction of a photograph, preferably a photograph of the holder of a document, such as an ID card, driving license, admission card. 5 10
14. The secured polymer substrate according to claim 13, **characterized in that** the document is a multi-layer document, wherein at least the outer layer is a layer of carbonizable material or a layer coated with a film of carbonizable material provided with a tactile relief marking with an emboss effect. 15

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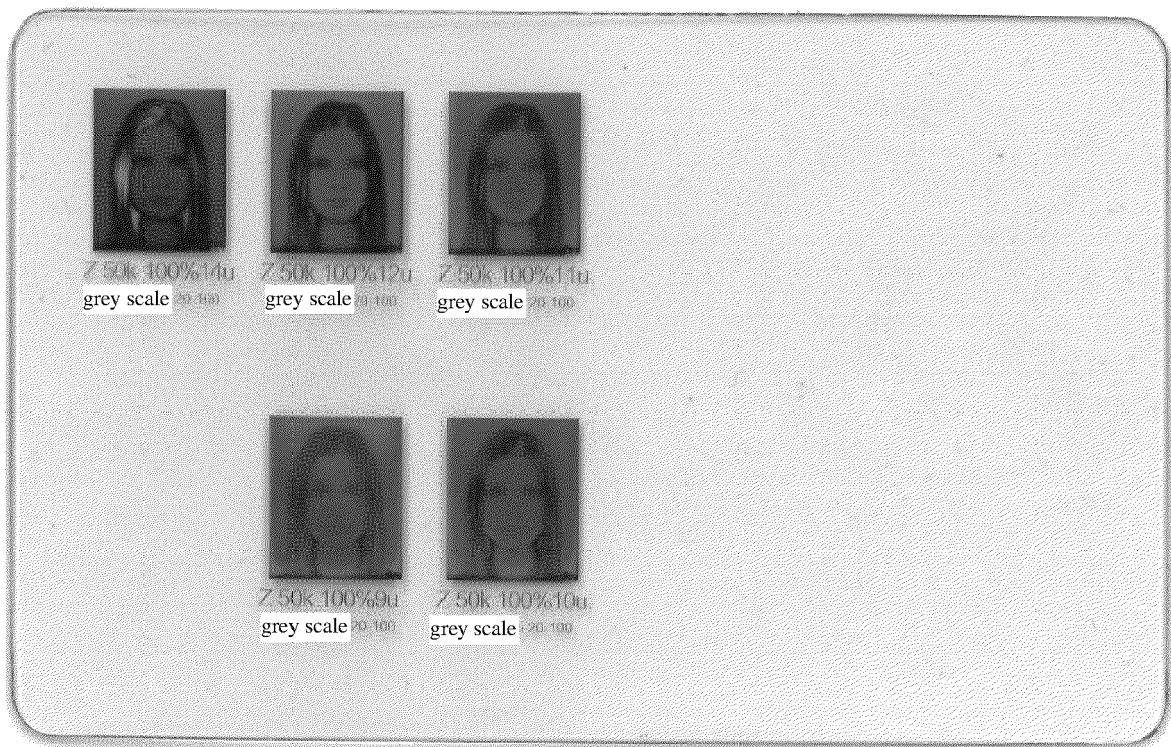


Fig. 1

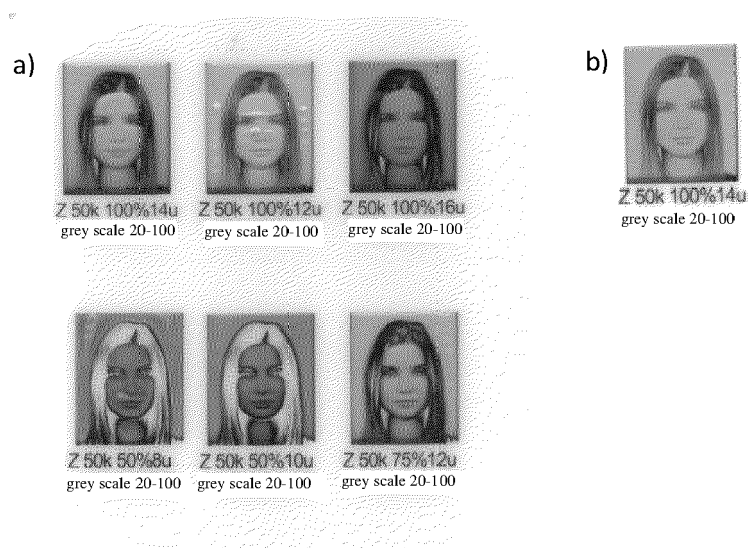


Fig. 2

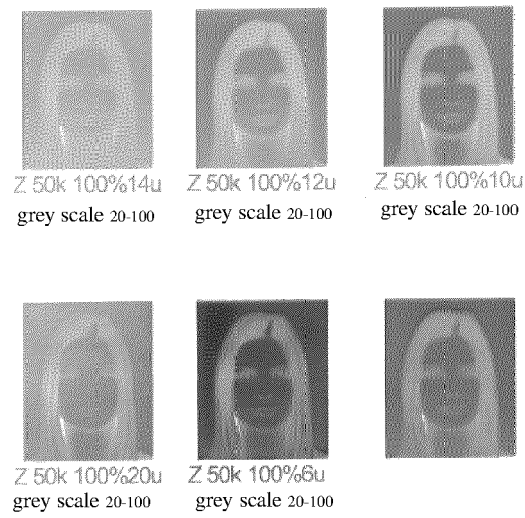


Fig. 3



Fig. 4



Fig. 5

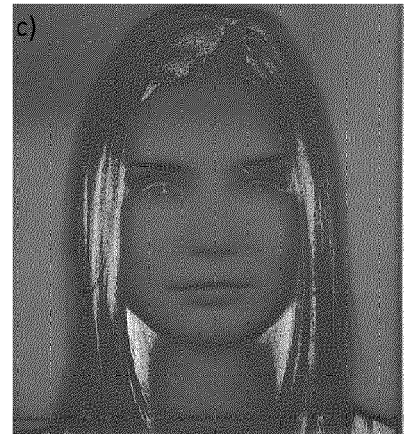
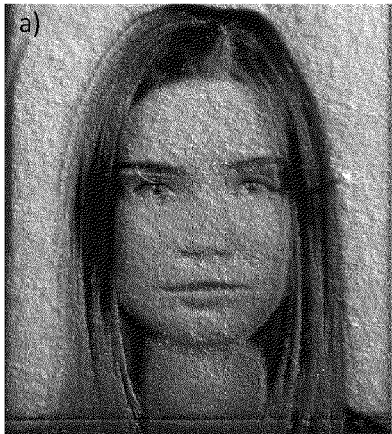


Fig. 6

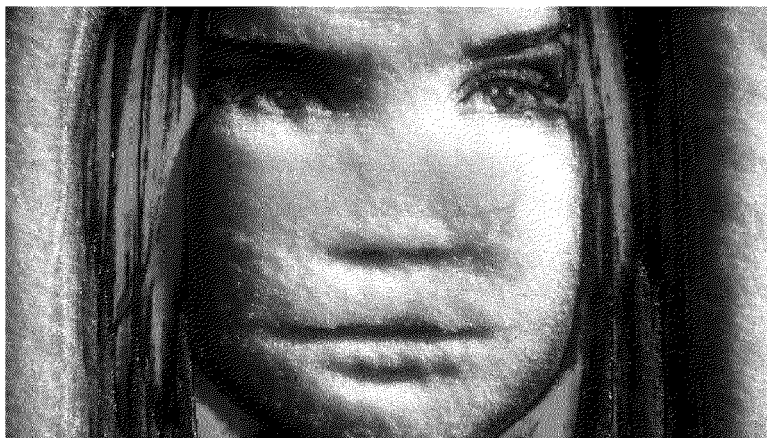


Fig. 7



Fig. 8

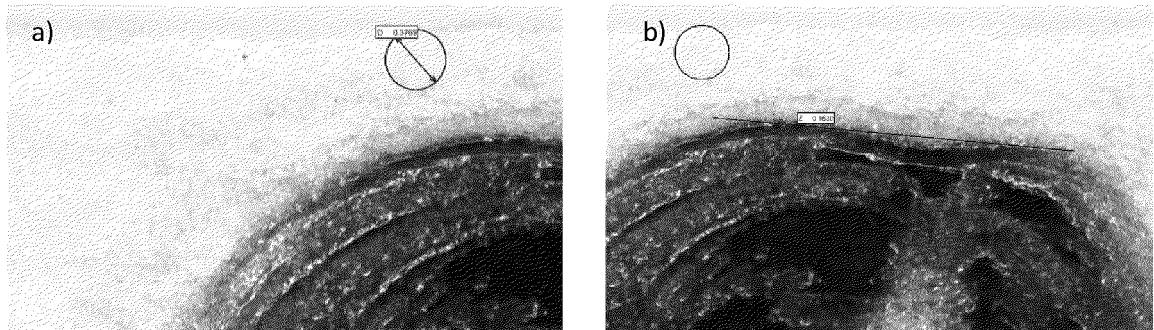


Fig. 9



Fig. 10

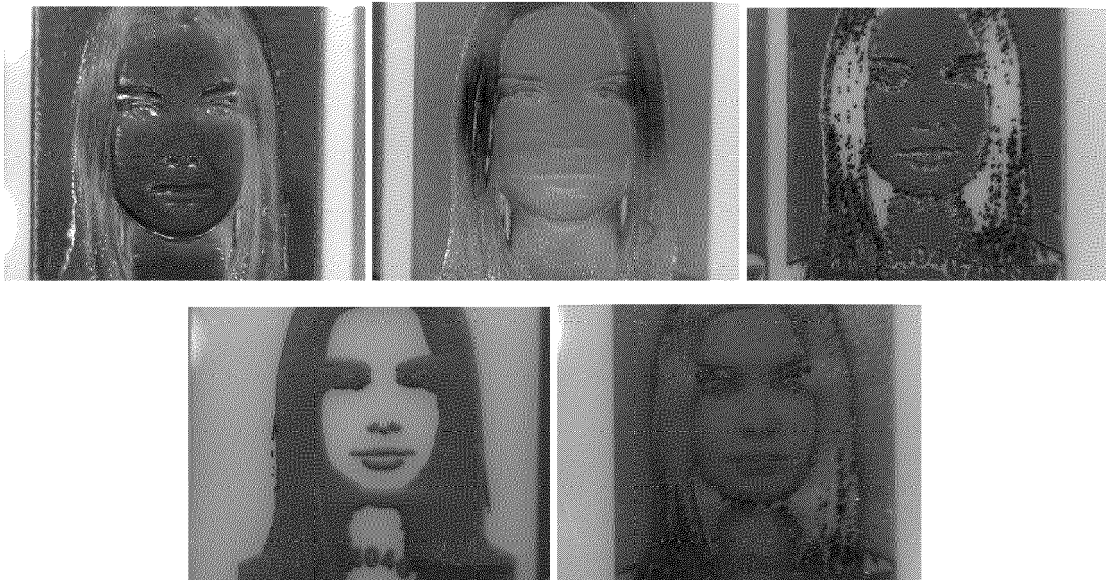


Fig. 11



EUROPEAN SEARCH REPORT

Application Number

EP 22 21 7005

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2014/227487 A1 (WARWICK DENNIS J [US]) 14 August 2014 (2014-08-14) * the whole document * -----	1-14	INV. B42D25/309 B42D25/324 B42D25/41 B42D25/425
			TECHNICAL FIELDS SEARCHED (IPC)
			B42D
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
Munich		31 May 2023	Achermann, Didier
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			

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EP 22 21 7005

5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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31-05-2023

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