



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
15.11.2023 Bulletin 2023/46

(51) International Patent Classification (IPC):
G07D 7/2033^(2016.01) G07D 7/20^(2016.01)

(21) Application number: **22172375.2**

(52) Cooperative Patent Classification (CPC):
G07D 7/2033; G07D 7/2016

(22) Date of filing: **09.05.2022**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

(72) Inventors:
• **Jaeger, Sebastian**
56412 Heiligenroth (DE)
• **Kohlert, Christian**
56414 Oberahr (DE)

(74) Representative: **Peterreins Schley**
Patent- und Rechtsanwälte PartG mbB
Hermann-Sack-Straße 3
80331 München (DE)

(71) Applicant: **Klöckner Pentaplast Europe GmbH & Co. KG**
56412 Heiligenroth (DE)

(54) **PRODUCT AUTHENTICATION USING MANUALLY APPLIED MARKS**

(57) In a first aspect, the present disclosure relates to a method for an optical product authentication. The method comprises manually marking 100 an authentic product with one or more authenticating marks with a hand-held writing instrument dispensing an ink. The method further comprises recording 200 on a mobile device one or more reference images including the one or more authenticating mark and, optionally, transmitting 300 the one or more reference images to a server. In addition, the method further comprises recording 400 on a mobile device one or more authentication images of a product to be authenticated including one or more authenticating marks. Further, the method comprises comparing 500 the one or more authentication images with the one or more reference images. The comparing 500 comprises identifying 510 one or more unique surface textures of the one or more authenticating marks within the one or more reference images and within the one or more authentication images, wherein the one or more unique surface textures comprises irregularities in shape, color, color intensity and/or brightness which are caused by manually marking 100 an authentic product with one or more authenticating marks. Subsequently, the comparing 500 comprises comparing 520 one or more of the identified unique surface textures of the one or more reference images to the one or more identified unique surface textures of the one or more authentication images. The method according to the first aspect further comprises indicating 610 a positive authentication if the one or more unique surface textures of the authenticating mark sufficiently match in the least one authentication images and the at least one reference images, or indicating 620 a negative authentication if the more unique

surface textures of the authenticating mark do not sufficiently match in the least one authentication images and the at least one reference images.

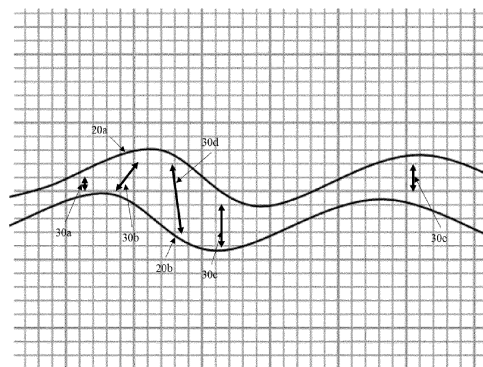


Figure 11

Description

Technical Field

[0001] The present invention relates to the field of product authentication. More specifically, the present invention relates to manually applied authentication marks and their verification.

Background

[0002] There is a growing and ongoing interest in the development of robust methods, security marks and systems for optical product authentication. More recently, the methods for product authentication using mobile device, e.g. smartphones, have become a focal point. Some prior art techniques use security marks based on randomly distributed features (e.g., particles, fibers, etc.). The user may take an authentication image of said randomly distributed features using a mobile device and have it compared to a reference image to identify whether the product is authentic.

[0003] The randomly distributed features may be printed on the product to be authenticated, however, this requires the use of dedicated printers, or at least inks, for their application. Alternatively, the randomly distributed features may be comprised within a premanufactured mark, such as a film comprising particles, which may be subsequently attached to the product to be authenticated. However, this requires the user to carry such premanufactured marks. Additionally, the premanufactured marks may not be attachable to some surfaces, for example a film may not be attachable to a product exhibiting a complex geometry.

[0004] Therefore, there is a need in developing new efficient techniques capable of solving some or all of the above-mentioned problems.

Summary

[0005] In a first aspect, the present disclosure relates to a method for an optical product authentication. The method comprises manually marking 100 an authentic product with one or more authenticating marks with a hand-held writing instrument dispensing an ink. The method further comprises recording 200 on a mobile device one or more reference images including the one or more authenticating mark and, optionally, transmitting 300 the one or more reference images to a server. In addition, the method further comprises recording 400 on a mobile device one or more authentication images of a product to be authenticated including one or more authenticating marks. Further, the method comprises comparing 500 the one or more authentication images with the one or more reference images. The comparing 500 comprises identifying 510 one or more unique surface textures of the one or more authenticating marks within the one or more reference images and within the one or

more authentication images, wherein the one or more unique surface textures comprises irregularities in shape, color, color intensity and/or brightness which are caused by manually marking 100 an authentic product with one or more authenticating marks. Subsequently, the comparing 500 comprises comparing 520 one or more of the identified unique surface textures of the one or more reference images to the one or more identified unique surface textures of the one or more authentication images. The method according to the first aspect further comprises indicating 610 a positive authentication if the one or more unique surface textures of the authenticating mark sufficiently match in the least one authentication images and the at least one reference images, or indicating 620 a negative authentication if the more unique surface textures of the authenticating mark do not sufficiently match in the least one authentication images and the at least one reference images.

Description of the figures

[0006]

FIG. 1 shows a flow diagram illustrating a method for an optical product authentication according to the first aspect.

FIG. 2A shows a flow diagram illustrating a method for identifying authenticating marks in one or more reference and authentication images.

FIG. 2B shows a flow diagram illustrating a method for identifying at least one edge region in one or more reference and authentication images.

FIG. 3 shows a flow diagram illustrating a method for identifying coordinates of one or more unique surface textures of one or more authenticating marks.

FIG. 4 shows a flow diagram illustrating a method for identifying a plurality of distances between two edges.

FIG. 5 shows a flow diagram illustrating a method for identifying a relative coordinates of one or more unique surface textures.

FIG. 6 shows a flow diagram illustrating a method for determining whether a product is authentic or counterfeit.

FIG. 7 shows a flow diagram illustrating methods for digital compensation .

FIG. 8 shows a flow diagram illustrating a method for digital compensation

FIG. 9 shows a flow diagram illustrating a method

for instructing a user during recording of images.

FIG. 10 shows a mark applied on paper with a writing instrument.

FIG. 11 shows a schematic of determining a plurality of distances between two edges according to a method according to the present disclosure.

Definitions

[0007] In the following, a number of terms and features will be explained which will be frequently used in the detailed specification.

[0008] The term "reference image" used in the present disclosure is not particularly limited and may include an image (for example, a digital image constituted by an area of pixels) recorded by a mobile device at the stage of registering or marking an authentic product. Moreover, the term "reference image" should be broadly construed to not only include an original digital image captured by an imaging device but also information obtained by digitally post-processing the corresponding digital image recorded by the imaging device. For instance, the term "reference image" may also include information regarding the location, size and color of particles or trigonometric information regarding a set of particles which is obtained by digitally processing the recorded digital image. For example, said digital images may be represented in an image space with pixel representation, wherein each data point is defined by a set of discrete quantities such as, e.g., its spatial coordinates and a color.

[0009] Likewise, the term "authentication image" according to the present disclosure is not particularly limited and may include a digital image recorded by an imaging device, for example, by a mobile device, such as a smart phone camera or a tablet, at the stage of authentication a product by a user. As for the aforementioned reference images, the term "authentication image" as used herein may not only include an original digital image captured by an imaging device, but also information obtained by digitally post-processing the corresponding digital image recorded by the corresponding imaging device.

[0010] Along the same lines, the term "projection image" is not particularly limited and may *i.a.* involve projecting the entirety or a part of the authentication or reference image or projecting the entirety or a part of information derived by digitally processing the reference or authentication image. In some non-limiting examples, this may include projecting the entirety or a part of information derived by digitally post-processing the reference image on the authentication image, or vice versa, projecting the entirety or a part of information derived by digitally post-processing the authentication image on the reference image.

[0011] The term "ink" may *i.a.* refer to its common meaning in the art. Additionally or alternatively, the term "ink" may refer to a gel, sol, or solution that contains at

least one colorant, such as a dye or pigment. The term "ink" within this description may also refer to "invisible inks". The term "invisible ink" may *i.a.* refer to its common meaning in the art. Additionally or alternatively, the term "invisible ink" may refer to a gel, sol, or solution which is invisible to the human eye under normal daylight conditions (after drying of the ink). In particular, the term "invisible ink" may refer to an ink only visible when illuminated by ultraviolet light.

[0012] The term "texture" within this description may *i.a.* refer to its common meaning in the art when referring to a visual (and not tactile) surface characteristic/appearance. Additionally or alternatively, the term "texture" may refer to the distribution of pigment particles and/or distribution of dye concentrations on a surface.

[0013] The term "orientation mark" as used in the present specification is not particularly limited and may refer to visual features provided on a product, e.g., on a packaging of the product. For example, a label, human-readable information such as a word or a sentence, a QR-code, a barcode or a geometric feature such as a rectangle provided on the packaging of the product may represent orientation marks. Orientation marks may also include only a part of the label, QR-code, barcode, etc. Additionally or alternatively, in some embodiments, the term "orientation mark" may refer to a printed, embossed, engraved or etched feature. Additionally or alternatively, in some embodiments, the term "orientation mark" does not refer to pigments or particles individually discernible to the human eye, for instance pigments or particles having a particle size of above about 50 μm , more specifically above about 100 μm , and in particular above about 500 μm .

[0014] The term "reflective particles" used in the present specification can refer to particles or pigments which possess a high reflectance (for example, equal to or larger than about 50% or equal to or larger than about 90%), at least particularly, in the visible spectrum (*i.e.*, for wavelengths from about 380 to about 750 nanometers) or in a certain narrow range within the visible spectrum. Thus, said particles may be able to reflect a significant part of an incident electromagnetic radiation coming, e.g., from an LED light, a flash or an ambient light. In some examples, the particles or pigments can reflect almost all or a significant part of the incident light (for example, equal to or larger than about 90% or equal to or larger than about 50%) back to its source with negligible scattering, in which case they may be referred to as the retroreflective particles (e.g., spherical particles made of glass or titanium dioxide may possess this property). In other examples, the "reflective particles" can reflect a significant part of an incident radiation (for example, equal to or larger than about 90% of the incident radiation, or equal to or larger than about 50% of the incident radiation) in a narrow spectral range (for instance, within about 1% or less of the visible spectrum, or within about 10% or less of the visible spectrum, or within about 20% or less of the visible spectrum) depend-

ing on the angle of view and/or on the angle of incidence. In this case, the reflective particles may be referred to as iridescent particles or pigments (the iridescent effect is based on diffraction or interference known in the art), which in some examples may comprise a substrate material such as mica, silicate or aluminum oxide coated, for example, with titanium dioxide, iron oxide or chromium oxide.

[0015] Accordingly, the term "luminescent particles" may refer to particles or pigments that comprise a luminescent material (for instance, to an extent of about 20 to about 100 wt% or of about 50 to about 100 wt%). The term "luminesce" as used herein should be construed broadly including different types of luminescence known in the art, such as, for example, phosphorescence and/or fluorescence. The "luminescent particles" of the present specification are capable of luminescing (i.e., emitting) light after being excited with electromagnetic radiation that lies in the corresponding spectral range (e.g., in the ultraviolet (UV) or infrared (IR) range contained, for example, in an ambient light) provided by one or more absorption lines of the constituent luminescent materials. In some embodiments, the luminescent particles are excited by an LED light or a flash and their absorption spectra lies in the visible range. The spectral range of the luminescent light (i.e., the color of the light emitted by the excited particles) may be varied by using different luminescent materials or their mixtures. In some embodiments, the "luminescent particles" may luminesce light in the visible spectrum. In other embodiments, the process of luminescence may take place in the non-visible range. The luminescence lifetime of the luminescent particles (is the parameter that describes the decay of the luminescent particles from the excited state to their lower energetic states (e.g., to the ground states) after turning off of the pumping electromagnetic radiation (e.g. a flash). For example, the luminescence lifetime (or decay time as used herein) may be defined based on the luminescence radiation emitted by the excited luminescent particles, for instance, based on its decaying intensity (e.g., exponentially decaying intensity). Thus, the decay time may be defined as the time at which the luminescence intensity reduces by e times as compared to its initial (or/and maximal) value. In other examples, the decay time may be defined as a half-life time, i.e., the time required for its initial (or/and maximal) value to decrease to half that value. Alternatively or additionally, the decay time may characterize an exponential decay of the excited luminescent particles, i.e., the decay time may be defined as a time during which a number of initially excited luminescent particles reduces by e times. In other examples, the decay time may be defined as a half-life time, i.e., the time required for the number of the initially excited luminescent particles to decrease to half the initial value. In still other examples, the luminescence lifetime may be referred to the average time the luminescent particle spends in its excited state before a photon is emitted. The decay time may depend on the constituent lumines-

cent materials and can vary in a large time interval, for instance, from about 1 millisecond to about 10 hours. In some examples, when the decay time is short (for instance, smaller than or equal to about 600 s specifically smaller than or equal to about 60 s and in particular smaller than or equal to about 15 s, particles excited by, for example, a flash from a smartphone can emit an amount of radiation which is sufficient to allow authentication under poor lighting conditions (e.g. relatively bright ambient lighting conditions) in a time period which is short enough to allow authentication on a mobile device by an end-user.

[0016] The term "plurality of randomly distributed reflecting and/or luminescent particles", or like expressions, is not particularly limited and generally corresponds to the number of particles required to allow a digital compensation of deviations between one or more reference image and one or more authentication image. The number of required particles can be as low as three for some authentication methods, however, larger numbers may be useful in other methods.

Detailed Description

[0017] An overview over the first aspect of the present disclosure related to a method for an optical product authentication will be given in connection with flow chart shown in Figure 1. The flow diagram 1, as well as the flow diagrams of Figures 2 to 9, show some method steps arranged in black boxes. The black boxes indicate that the method steps ordered below a method step at the top may be comprised within the method step denoted at the top.

[0018] In a first aspect, the present disclosure relates to a method for an optical product authentication. The method comprises manually marking 100 an authentic product with one or more authenticating marks with a hand-held writing instrument dispensing an ink. The method further comprises recording 200 on a mobile device one or more reference images including the one or more authenticating mark and optionally transmitting 300 the one or more reference images to a server. In addition, the method further comprises recording 400 on a mobile device one or more authentication images of a product to be authenticated including one or more authenticating marks. Further, the method comprises comparing 500 the one or more authentication images with the one or more reference images. The comparing 500 comprises identifying 510 one or more unique surface textures of the one or more authenticating marks within the one or more reference images and within the one or more authentication images, wherein the one or more unique surface textures comprises irregularities in shape, color, color intensity and/or brightness which are caused by manually marking 100 an authentic product with one or more authenticating marks. Subsequently, the comparing 500 comprises comparing 520 one or more of the identified unique surface textures of the one or more ref-

erence images to the one or more identified unique surface textures of the one or more authentication images. The method according to the first aspect further comprises indicating 610 a positive authentication if the one or more unique surface textures of the authenticating mark sufficiently match in the least one authentication images and the at least one reference images, or indicating 620 a negative authentication if the more unique surface textures of the authenticating mark do not sufficiently match in the least one authentication images and the at least one reference images.

[0019] The method according to the first aspect may for example allow the exchange of goods between a first and second user. The first user may manually mark 100 an authentic product with a writing instrument comprising an ink. For example, the first user may draw a line on the back of an artwork with the writing instrument. Subsequently, the first user may then record 200 on a mobile device, such as a smartphone, one or more reference images of the mark he marked 100 on the artwork. The mobile device may optionally then, automatically or prompted by the user, transmit 300 the one or more reference images to the server. The first user may subsequently ship the authentic product to the second user. The second user may then authenticate that he has received the authentic product by recording 400 with a mobile device one or more authentication images of the product to be authenticated, in particular the part of the product to be authenticated carrying one or more authenticating marks. The one or more authentication images may optionally then also be transmitted to the server or the one or more reference images downloaded from the server onto the mobile device.

[0020] The one or more reference images and the one or more authentication images may then be compared 500. Manually marking with a writing instrument leads to the formation of unique surface textures. When drawing two lines with the same writing instrument, the lines will be different. Figure 10 shows the texture of a line drawn with a writing instrument. As is shown in Figure 10 the edges of the line is not uniform, but comprises sections where the line is wider or thinner. Additionally, the amount of ink deposited may not be uniform within the line itself. This may lead to parts of the line exhibiting a different color intensity and/or brightness. Further, in particular as the authentic product may be colored, the different amounts of deposited ink may also lead to variations of the color within the ink. Additionally, these unique surface textures may exhibit small dimensions and may be difficult to reproduce. In particular, if a plurality of unique surface textures is formed these may be difficult to reproduce, as a forgery would need to copy both geometric features, as well as, color, color intensity and brightness features. Further, the distribution of the unique surface textures may be influenced by the underlying substrate. For example, when marking paper comprising pores, the pores may absorb the ink leading to the pores appearing darker and/or having a higher color intensity. A forger

may attempt to copy the authenticating mark by printing. However, the if counterfeit also comprises paper, the pores would also influence the ink being deposited on it by the printer leading to different unique surface textures.

[0021] The unique surface textures of the one or more authenticating marks occurring when marking 100 an authentic product are then identified 510 in the one or more authentication images and reference images. Subsequently, the identified unique surface textures of the one or more reference and authentication images are compared 520. It should be noted that the comparison 500 may include additional steps. As outlined later within this disclosure, the comparison 500 may include a digital transformation of the one or more authentication or reference images. The comparison 500 therefore does not necessarily need to occur directly between the one or more authentication and reference images.

[0022] The second user is then indicated 610 of a positive authentication if the one or more unique surface textures of the authenticating mark sufficiently match in the least one authentication images and the at least one reference images. Alternatively, the second user may also be indicated 620 a negative authentication if the more unique surface textures of the authenticating mark do not sufficiently match in the least one authentication images and the at least one reference images. The second user can thereby ascertain whether the authentic product has been shipped to him, or a third person has exchanged the authentic product for a counterfeit prior to the delivery to the second user.

[0023] The method may also be used only by the first user. For example, the first user may mark an authentic product, such as an artwork, and lend it to the second user for a duration. When the second user returns a product, the first may authenticate whether the returned product is the authentic product.

[0024] Without wishing to be bound by theory, it is believed that formation of the unique surface textures during the manual marking 100 is influenced by a plethora of conditions. Among these conditions may be the temperature, which may influence the viscosity of the ink, the porosity and pore distribution of the authentic product, the pressure the user applies during the marking process or features of the writing instrument, such as defects in the writing ball of a ballpoint pen. In particular the interplay of these features, each requiring to be perfectly copied to copy the authenticating mark, lead to a high the degree of counterfeit protection from the method according to the first aspect.

[0025] Figures 2 to 9 show flow diagrams of additional steps the method according to the first aspect may comprise.

[0026] In embodiments, the method may comprise identifying 210 the one or more authenticating marks in the one or more reference images and identifying 410 the at least one authenticating mark in the one or more authentication images. The method may identify 210, 410 the authenticating mark to only process data related to

said authenticating mark or for other process steps, such as instructing the user to align the mobile device in a specific way, as will be explained later on. Identifying 210 the one or more authenticating marks in the one or more reference images and identifying 410 the at least one authenticating mark in the one or more authentication images may occur during the recording step 200 and recording step 400 or during the comparing step 500. In Figure 2A the steps identifying 210 the one or more authenticating marks in the one or more reference images and identifying 410 the at least one authenticating mark in the one or more authentication images are shown as parts of the recording steps 200, 400.

[0027] As shown in Figure 2A, the method may comprise identifying 220 at least one edge region of the one or more authenticating marks in the one or more reference images and identifying 420 at least one edge region of the one or more authenticating marks in the one or more authenticating images. The method may further comprise comparing the one or more unique surface textures in the at least one edge region of the reference image with the one or more unique surface textures in the at least one edge region of the authenticating image. As stated above, two lines drawn with the same writing instrument by the same user will have a unique texture of edges. As a result, by identifying 220, 420 the at least one edge region of the one or more authenticating marks and subsequently comparing these, the authenticity of a product may be checked. The steps of identifying 220, 420 the at least one edge region of the one or more authenticating marks may occur during the recording step 200 and recording step 400 or during the comparing step 500. In Figure 2B the steps of identifying 220, 420 the at least one edge region of the one or more authenticating marks are shown as parts of the comparing step 500. Identifying 220, 420 the at least one edge region of the one or more authenticating marks may also be used to instruct the user to align the camera, as it outlined below within this disclosure.

[0028] As depicted in Figure 3, identifying 510 the one or more unique surface textures of the one or more authenticating marks may comprise determining 530 coordinates representing relative positions of the color, color intensity and/or brightness. Determining 530 the coordinates representing the relative positions may comprise placing 540 a grid over the one or more reference images and/or the one or more authentication images to form a first plurality of boxes. Determining 530 the coordinates representing the relative positions may further comprise determining 550 the relative position and the color, color intensity and/or brightness of a second plurality of boxes, or determining 560 the relative position and the color, color intensity and/or brightness of a second plurality of boxes disposed within the one or more authenticating marks. Determining the relative position may allow comparing the unique surface textures in the one or more authentication and/or reference image independent of a recording angle used during the recordings 200, 400.

[0029] In some embodiments, the second plurality of boxes may be the same as the first plurality of boxes. By determining 530 only the coordinates within the authentication mark the processing duration of the method may be reduced, as well as the amount of data storage required to store the determined coordinates.

[0030] In some embodiments, the one or more reference images and/or the one or more authentication images may be high-resolution images. More specifically, the image may have at least 2,073,600 pixels, in particular at least 3,686,400 pixels.

[0031] In some embodiments, the width of each box of the first and/or second plurality of boxes may be between 5 μm to about 100 μm , more specifically between about 10 μm to about 50 μm and in particular between about 20 μm to about 30 μm . In some embodiments, the length of each box of the first and/or second plurality of boxes may be between 5 μm to about 100 μm , more specifically between about 10 μm to about 50 μm and in particular between about 20 μm to about 30 μm . In some embodiments, the width of each box of the first and/or second plurality of boxes may be between 0.5 μm to about 10 μm , more specifically between about 1 μm to about 5 μm and in particular between about 2 μm to about 3 μm . The length of each box of the first and/or second plurality of boxes may be between 0.5 μm to about 10 μm , more specifically between about 1 μm to about 5 μm and in particular between about 2 μm to about 3 μm . In particular, each box may be a square. The term "width of each box" corresponds to the length of the product covered. For example, an image of an authentic product is recorded 200, wherein the authentic product fills the complete image and has a size of 100 mm x 100 mm. The image may be divided into a total of 10,000 x 10,000 boxes. Hence, each box has a width corresponding to 10 μm of a length of the authentic product.

[0032] In some embodiments, an area of each box of the first and/or second plurality of boxes may correspond to an area of a pixel of the one or more reference images and/or the one or more authentication images. The pixel may be smallest unit of information within an image recorded 200, 400 by a mobile device. As a result, analyzing each box, wherein each box corresponds to a pixel may allow deriving a maximum of data from the one or more reference and authentication images. The width of the boxes, in particular when each box corresponds to a pixel, may depend on the distance from the authentic product or product to be authenticated during recording 200, 400. Further, the width of the boxes may depend on the resolution the mobile device is able to provide.

[0033] In some embodiments, the color of each box or coordinate may be identified as the box's average or the coordinate's a*-value and b*-value in the CIELAB color space or h°-value in CIELCh color space. The brightness of each box or coordinate may be identified as the box's average or the coordinate's L*-value in the CIELAB color space. Additionally or alternatively, the color intensity of each box or coordinate may be identified as the box's

average or the coordinate's C*-value in the CIELCh color space. The CIELAB and CIELCh color space may be used to identify the unique surface textures in the form of numerical values. Alternatively or additionally, the color, brightness and/or color intensity may also be identified as values in an RGB color space.

[0034] The one or more authenticating mark may comprise at least two edges. For example, if the authenticating mark is a line, the at least two edges may be the edges confining the line. Figure 10 shows an image of a line drawn with a writing instrument using an ink. The image was recorded by a mobile device. The two edges confining the drawn line are schematically represented by the lines 10a, 10b. As depicted in the flow chart Figure 4, identifying 510 the one or more unique surface textures may comprise determining 1530 a plurality of distances between the at least two edges. Determining 1530 the plurality of distances between the at least two edges may comprise identifying 1540 the at least two edges. Identifying 1540 the at least two edges may comprise identifying 1550 an unmarked area and setting 1555 a threshold value and/or threshold range based on the color, color intensity and/or brightness to a value of the unmarked area. Further, identifying 1540 the at least two edge may comprise identifying 1560 marked coordinates representing the relative positions of the color, color intensity and/or brightness deviating from the unmarked area's threshold value and/or threshold range. Additionally, identifying 1540 the at least two edges may comprise identifying 1570 edge coordinates representing the relative positions which neighbor coordinates of the unmarked area and marked coordinates and identifying 1580 inner marked coordinates representing the relative position which neighbor only marked coordinates. Identifying 1540 the at least two edges as may be performed for example on a piece of paper. The threshold value may be for example based on the brightness value of the paper without markings. When the paper was manually marked 100 with an ink comprising dark pigments or dyes, the authenticating mark may exhibit a brightness value significantly lower than that of the paper. Hence, coordinates having a brightness value falling below the threshold value based on the brightness value of the paper may be identified 1560 as marked coordinates. In the example, the edges are naturally those coordinates of the authenticating mark, which have brightness falling below the threshold value and bordering coordinates which have a brightness above or at the threshold value, hence, unmarked paper. The result of the above described process may not lead to lines as represented by 10a and 10b, but rather to three sets of coordinates, namely unmarked coordinates, marked coordinates and edge coordinates. Specifically, the edge coordinates may be those pixels the sketched lines 10a and 10b cross through, the marked coordinates may be those pixels lying between the lines 10a and 10b and the unmarked coordinates may be those coordinates lying outside of the two lines 10a and 10b.

[0035] In some embodiments, determining 1530 the plurality of distances between the at least two edges comprises determining 1590 a plurality of shortest straight lines connecting two of the edge coordinates while crossing at least one marked coordinate. Figure 11 shows a schematic of the determination 1590 of the plurality of shortest straight lines 30a to 30e connecting two of the edge coordinates while crossing at least one marked coordinate. The edges of the line are denoted by the numerals 20a and 20b. As depicted in Figure 11, each of the shortest straight lines connects two edge coordinates wherethrough the edges 20a and 20b run. As depicted in Figure 11, each coordinate corresponds to a box. The plurality of shortest straight lines may then form a unique dataset to identify the authentic product. For example, the unique dataset may comprise the lengths and/or the distribution of the plurality of shortest straight lines.

[0036] As shown in Figure 5, identifying 510 the one or more unique surface textures may comprise determining 2530 a plurality of relative coordinates of a subset of coordinates. As outlined in Figure 5, determining 2530 the plurality of relative coordinates of the subset of coordinates may comprise identifying 2540 the subset of coordinates, wherein the subset of coordinates comprises a plurality coordinates exhibiting the highest brightness and/or color intensity and/or the lowest brightness and/or color intensity. Further determining 2530 the plurality of relative coordinates of the subset of coordinates may comprise determining 2550 one or more distances and/or one or more angles between the plurality of coordinates as the plurality of relative coordinates. For example, by determining two lengths and one angle or two angles and one length or three length, a triangle formed by three coordinates can be unambiguously defined. Multiple triangles may be computed to define a unique dataset based on the authentication mark. For instance, the angular relationship between coordinates may be an information that is attributed to selected coordinates. In some examples, when three (e.g. the brightest) coordinates on the reference image are selected, the values of three angles of the triangle formed by these three coordinates can be determined to characterize their relative positions. This method is described in more detail in e.g. EP 2 318 286 B1 for particles which is incorporated herein by reference thereto. In other examples, if more than three coordinates are used, then a plurality of triangles can be formed, each triangle being formed by any specific combination of three coordinates from the subset of coordinates.

[0037] The method according to the present disclosure comprises indicating 610 a positive authentication if the one or more unique surface textures of the authenticating mark sufficiently match in the least one authentication images and the at least one reference images; or indicating 620 a negative authentication if the more unique surface textures of the authenticating mark do not sufficiently match in the least one authentication images and the at least one reference images.

[0038] Due to factors, such as contamination of the authentic product, for example dirt on the authentication mark, the one or more authentication images and reference images may not be perfectly equal. Hence, in some embodiments, as shown in Figure 6, the comparing 500 may include calculating 550 a measure of deviation between the one or more authentication images and the one or more reference images. The calculated 550 measure of deviation may be used to identify whether unique surface textures sufficiently match in the one or more authentication and reference images.

[0039] Such a measure of deviation may be useful in reliably determining whether a product is fraudulent or not, for instance by allowing a certain degree of tolerance in the authentication method and, thus, preventing false-negative results. In some examples, the measure of deviation may be based on a set of ratios between the differences in for example the determined coordinates representing relative positions, the shortest straight lines or the color intensities. For example, the measure of deviation can be an average ratio calculated within the set of ratios mentioned above. In examples, the measure of deviation can be based on a set of ratios between the differences in the respective attributed information of the identified unique surface textures, i.e., the information representing any one or more of the determined coordinates representing relative positions, the shortest straight lines or the color intensities. For example, the measure of deviation can be an average ratio calculated within the set of ratios related to any one or more of the i.e., the determined coordinates representing relative positions, the shortest straight lines or the color intensities.

[0040] The predetermined threshold value is not particularly limited and may depend on the authentication principle used and the degree of false-positive and false-negative results considered to be acceptable for the particular application. For example, the product to be authenticated can be classified as authentic if the (average) ratio with respect to the differences in the attributed coordinates or in the attributed information disclosed further above does not exceed the value of about 0.001, or the value of about 0.01, or the value of about 0.1, or the value of about 0.25. In other examples of the present disclosure, the indication 610, 620 may involve indicating the product to be authenticated as authentic if the measure of deviation is larger than a predetermined threshold value and otherwise classifying the product to be authenticated as counterfeit. For example, the product to be authenticated can be classified as authentic if the measure of deviation based on the average ratio with respect to the differences in the attributed coordinates or in the attributed information, e.g., when the measure of deviation is inversely proportional to said average ratio, is larger than the value of about 1000, or the value of about 100, or the value of about 10, or the value of about 4. Such ratios may be particularly useful in the aforementioned examples.

[0041] Hence, the method may comprise determining

(600) whether the product to be authenticated is the authentic product or a counterfeit product, wherein determining (600) whether the product to be authenticated is the authentic product or a counterfeit product comprises classifying (610) the product to be authenticated as authentic if the calculated (550) measure of deviation is smaller than a predetermined threshold value and otherwise classifying (620) the product to be authenticated as counterfeit, or classifying (610) the product to be authenticated as authentic if the calculated (550) measure of deviation is larger than a predetermined threshold value and otherwise classifying (620) the product to be authenticated as counterfeit.

[0042] In some examples, the predetermined threshold value may depend on a specific measure of deviation or several measures of deviations selected for the classification step. For example, a predetermined threshold value may depend on an average ratio based on the differences in the attributed coordinates or on the differences in the attributed information regarding the determined coordinates representing relative positions, the shortest straight lines or the color intensities. In other examples, the predetermined threshold value may take into account service provider or user preferences. In some examples, this may imply that the predetermined threshold value is selected depending on the risk of false positives (i.e., when the product to be authenticated is classified as counterfeit while it is not) or false negatives (i.e., when the product to be authenticated is classified as authentic while it is not). In other words, the predetermined threshold value may depend on which of the two outcomes is less desirable in order to avoid possible frustration of a user. Thus, the predetermined threshold value may be individually set on a case-by-case basis to represent a desired balance between the degree of counterfeiting protection and degree of potential frustration of a user.

[0043] It should be understood that the term predetermined threshold value implies that the threshold value is determined prior the user of the mobile device requests an authentication via his/her device. However, this does not necessarily mean that the predetermined threshold value does not change over time, for instance due to feedback during use suggesting that the degree of false-negative or false-positive authentication results is too high. Such a dynamic "in-use" adaption of the predetermined threshold value may allow to manage and maintain an authentication process for a launched series of products and to balance user satisfaction vs. authentication needs in a dynamic process (e.g. in cases where it turns out after product launch that a larger-than expected portion of the security labels are soiled while on the shelf for sale producing too many false-negative results). Turning to the technical implementation, in some examples, the method of authentication may comprise the step of electronically receiving on the mobile device information regarding the predetermined threshold value from a server. In other examples, the method of authentication may

comprise the steps of modifying (e.g. calculating based on prior authentication results) a predetermined threshold, storing the modified predetermined threshold value on a server and electronically receiving on the mobile device information regarding the modified predetermined threshold value from the server.

[0044] In some embodiments, the ink dispensed by the writing instrument may comprise reflective and/or luminescent particles. In some embodiments, said reflective particles may be reflective, retroreflective or iridescent. In addition or alternatively, the ink may comprise plurality of randomly distributed luminescent particles. The luminescent particles may emit (i.e., luminesce) light, for example, in the visible range (i.e., wavelengths above about 380 nm and below about 750 nm), if they are excited with electromagnetic radiation (produced, for example, by an LED light, a flash, an ambient light or some other source providing UV light having the wavelength range of about 100 to about 380 nm or IR light having the wavelength range of about 750 to about 1000 nm). When the ink dispensed by the writing instrument comprises reflective and/or luminescent particles, the one or more authentication marks created by marking 100 an authentic product will also comprise reflective and/or luminescent particles. More specifically, the one or more authentication marks may comprise a plurality of reflective and/or luminescent particles, in particular a randomly distributed plurality of reflective and/or luminescent particles.

[0045] The reflective and/or luminescent particles may correspond to the one or more unique surface textures. For example, in particular after illumination, e.g. by flash, the reflective and/or luminescent particles may appear as coordinates with an increased brightness. As the particles are randomly distributed, in particular as the randomness may be influenced by the manual marking 100, the distribution may be difficult to counterfeit. In some embodiments, the particles may additionally have a particle size of less than about 200 μm , specifically less than about 100 μm and in particular less than about 50 μm . This may further help in frustrating counterfeiting attempts since particles of such small sizes are more difficult to reproduce with common copiers and printers

[0046] In some embodiments, the method may comprise digital compensation 700, wherein the digital compensation 700 comprises compensating deviations between the one or more authentication images and the one or more reference images. The digital compensation 700 is outlined in Figures 7 and 8.

[0047] The aforementioned reflective and/or luminescent particles which may be comprised within the one or more authentication marks may be used for the digital compensation 700. In some embodiments, the digital compensation 700 of the deviations may comprise identifying 710 coordinates of a plurality of reflective and/or luminescent particles disposed within the authenticating marks within the one or more reference images and identifying 720 coordinates of a plurality of reflective and/or luminescent particles disposed within the authenticating

marks within the one or more authentication images. The digital compensation 700 may further comprise determining 730 a deviation between the one or more reference images and in the one or more authentication images based on a digital image analysis, wherein said deviation is associated with a difference between the recording position relative to the plurality of reflective and/or luminescent particles in the one or more reference images and the recording position relative to the plurality of reflective and/or luminescent particles in the one or more authentication images. In addition the digital compensation 700 may comprise computing 750 a projection image by projecting 740 the one or more authentication images on the one or more reference images or the one or more reference image on the one or more authentication images based on the determined 730 deviation and comparing 500 the computed projection image with the one or more authentication images or the one or more authentication images. The plurality of reflective and/or luminescent particles may also referred to in the following as "plurality of particles".

[0048] In some embodiments, the method may comprise applying 1100 an orientation mark to the authentic product. In some examples, as mentioned above, the orientation mark may represent a visually well discernible feature (e.g., with a known shape) provided on the packaging of the authentic product such as, e.g., a label, QR-code, barcode or other features known in the art. In other examples, the first orientation mark may comprise only a certain (spatial) part of one or more of the listed features.

[0049] In some embodiments, the digital compensation 700 of the deviations may comprise identifying 1200 the orientation mark in the one or more reference images and identifying 1400 the orientation mark in the one or more authentication images. The digital compensation 700 may further comprise determining 1500 a deviation between the one or more reference images and in the one or more authentication images based on a digital image analysis, wherein said deviation is associated with a difference between the recording position relative to the one or more orientation marks in the one or more reference images and the recording position relative to the one or orientation marks in the one or more authentication images. Additionally the digital compensation 700 may comprise computing 750 a projection image by projecting the one or more authentication images on the one or more reference images or the one or more reference image on the one or more authentication images based on the determined 1500 deviation and comparing 500 the computed projection image with the one or more authentication images or the one or more authentication images.

[0050] As outlined above, the projection image may be computed 750 using the plurality of particles or the orientation mark. The recording position relative to the orientation mark may be different in the one or more authentication and reference images. In some examples,

the deviation between the one or more authentication and reference images can be directly mapped to the corresponding (physical) positions and/or perspectives of the imaging device (e.g., a digital camera) when recording the reference image and the camera of the mobile device (e.g., a smart phone camera or a tablet) when recording the authentication image. For example, the deviation between the digitally processed reference and authentication images may be discernable if a ratio of the distance (and/or angle) between the imaging device and the orientation mark or plurality of particles in the one or more authentication images to the distance between the camera on the mobile device and the orientation mark or plurality of particles in the one or more reference images is substantially different from unity (for example, less than or equal to about 0.8 or less than or equal to about 0.5 or less than or equal to about 0.2 or larger than or equal to about 1.2 or larger than or equal to about 2.0 or larger than or equal to about 5.0).

[0051] Using the orientation marks as recorded on the respective images may facilitate determining said deviation, as the orientation marks (representing, for example, the entirety or a part of label, QR-code, barcode etc. as noted above) are typically of a known shape and are visually well-identifiable features provided on the respective products.

[0052] Using the plurality of particles may facilitate the use of the method by the user. More specifically, the user may only be required to mark 100 the authentic product with an ink comprising the plurality of particles. The digital compensation 700 based on the plurality of particles may for example be based on determining the coordinates of the plurality of particles in the one or more reference images and subsequently determining the coordinates of the plurality of particles in the authentication image. The digital compensation 700 may then compute 750 a projection image based on the deviation of the coordinates of the plurality of particles. The coordinates of the plurality of particles may be determined akin any of the methods described for determining the coordinates of the unique surface textures.

[0053] In some embodiments, the step of digital compensation 700 can comprise mapping the orientation mark and/or plurality of particles as recorded 200 in the one or more reference images on the orientation mark and/or plurality of particles as recorded 400 in the one or more authentication images. For example, such mapping can include calculating an image transformation that maps the orientation mark and/or plurality of particles of the one or more authentication image on the one or more reference images, or vice versa. In some examples, calculating the image transformation can include applying algorithms for the digital compensation 700. For example, the digital registration can be used in calculating such the image transformation applied to the reference image that a deviation between the orientation mark and/or plurality of particles as recorded in the one or more reference images and the one or more authentication images is

minimal. In some examples, minimizing the deviation can include applying the image transformation to each pixel of the orientation mark or each pixel comprising a particle of the plurality of particles as recorded in the one or more reference image to match it with the corresponding pixel of the orientation mark or pixel comprising a particle of the plurality of particles as recorded on the authentication image. For example, said image transformation can include one or more of translation, scaling, rotation or displacement operations, as well as Euler transformation, similarity map, B-spline mapping or spline kernel transformation, which is a list of several non-exhaustive examples. In other examples, minimizing the deviation can include applying said image transformation to a preselected set of pixels of the orientation mark or pixels comprising a particle of the plurality of particles in the one or more reference images, for example, when transforming all pixels of the orientation mark or all pixels comprising a particle of the plurality of particles is computationally expensive or not possible at all due to limited hardware resources. In a next step, the image transformation can be iteratively improved by using different measures of deviations between the transformed pixels of the one or more reference image and the corresponding pixels of the one or more authentication images. In some examples, the transformed pixels of the orientation mark or pixels comprising a particle of the plurality of particles of the one or more reference image can be taken for this improvement procedure. In other examples, only the preselected set of pixels of the orientation mark can be sufficient for this purpose. For example, various measures of deviation may be considered for use in this context, such as, for example, the mean squared difference, mutual information, normalized mutual information, normalized correlation coefficient, kappa statistics, or other methods known in the art. Then, one or more of optimization procedures (e.g., gradient descent, nonlinear conjugate gradient, or Robbins-Monro algorithms) can be applied to iteratively converge to the optimal image transformation. In some examples, in particular with colored orientation marks, mapping the orientation mark of the one or more reference images to the orientation mark of the one or more authentication images can involve not only the use of spatial coordinates of pixels, but also their colors represented by a set of discrete quantities (e.g., by the RGB scheme).

[0054] In an example, the method of the present disclosure can further comprise recording a plurality of reference images including the orientation mark and/or plurality of particles and the authentication mark from a plurality of positions relative to the authentication mark of the authentic product. It should be noted that positions relative to the authentication mark are also relative to the position of the orientation mark and/or plurality of particles if these are present. In an example, the plurality of reference images may be recorded by the user with a mobile device after marking the authentic product. The mobile device may prompt and/or instruct the user on

recording the plurality of reference images. In some examples, the plurality of reference images can be recorded from a plurality of first recording angles relative to the authentication mark or from a plurality of first recording distances relative to the first authentication mark. In other examples, the plurality of reference images can be recorded from both a plurality of first recording angles relative to the authentication mark and from a plurality of first recording distances relative to the authentication mark. In some examples, two or more first recording angles from the plurality of first recording angles can be different from each other. In other examples, all of the first recording angles from the plurality of first recording angles can be different. In yet other examples, two or more first recording distances from the plurality of first recording distances can be different from each other. In still other examples, all of the first recording distances from the plurality of first recording distances can be different.

[0055] In a next step, a plurality of differences between the authentication mark, orientation mark and/or plurality of particles as recorded in the plurality of reference images and in the one or more authentication images can be calculated. In some examples, the plurality of differences between the authentication mark, orientation mark and/or plurality of particles as recorded in the plurality of reference images and in the one or more authentication images can be associated with a plurality of differences between the plurality of first recording angles and the second recording angle (i.e., the angle relative to the authentication mark at which the authentication image is recorded on the mobile device of the product to be authenticated). In addition or alternatively, said difference can be associated with a plurality of differences between the plurality of first recording distances and the second recording distance (i.e., the distance relative to the second orientation mark at which the authentication image is recorded on the mobile device of the product to be authenticated). In some examples, said plurality of differences can be calculated in a fashion similar to that disclosed further above. In some examples of the present techniques, the authentication mark, plurality of particles or orientation mark as recorded on the plurality of reference images can be mapped to the authentication mark, plurality of particles or orientation mark as recorded on the one or more authentication images. In other examples, the authentication mark, plurality of particles or orientation mark recorded on the authentication image can be mapped to the authentication mark, plurality of particles or orientation mark as recorded on the plurality of reference images.

[0056] In some examples, the method may include (as a next step) arranging the calculated plurality of differences in ascending or descending order. Then, one or more reference images having one or more smallest differences from the arranged plurality of differences can be selected from the plurality of reference images. In other examples, a plurality of weighting factors can first be

calculated by weighting the plurality of differences. This way may be efficient in embodiments where some differences from the plurality of differences are deemed to be, e.g., less important than the others. For example, the differences associated with recording distances may be considered less important than those associated with recording angles. In some examples, the next step can comprise arranging the calculated plurality of weighting factors in ascending or descending order. Then, one or more reference images can be selected from the plurality of reference images that have one or more smallest weighting factors from the arranged plurality of weighting factors. Thus, in some examples, this procedure allows selecting the one or more reference images that can be the best candidates for the subsequent authentication process, thereby skipping a computationally demanding comparison related to the analysis of the plurality of reflective and/or luminescent particles on all reference images with respect to the authentication image. Furthermore, in some examples, it may be useful to select a single reference image that is closest (or most similar) to authentication image (i.e. the reference image having the smallest difference or the smallest weighting factor as described above). It should be noted that in some examples, the one or more reference images selected from the plurality of reference images may not always be the same images, as their selection is directly dependent on the position of the mobile device relative to the authentication mark of the product to be authenticated when the authentication image is captured on the mobile device (e.g., different users may hold mobile devices in different positions with respect to the product to be authenticated).

[0057] In some examples of the present techniques, the suitability of particles for the authentication process may be analyzed on basis of the reference images. This may be advantageous in determining particles in the security label of the authentic product which may be more difficult to properly identify, for instance because they have a different shape or a different color impression when viewed from angles. Such particles may be classified as less suitable or unsuitable for the subsequent authentication process. This may help in increasing the robustness of the method by excluding less reliable particles from consideration.

[0058] Specifically, in some examples, the method may comprise analyzing a suitability of particles from the plurality of reflective and/or luminescent particles for the authentication process based on the recorded plurality of reference images. In some examples, analyzing the suitability can include classifying particles from the plurality of reflective and/or luminescent particles as being suitable or unsuitable for the authentication process or, in particular, classifying each particle from the plurality of randomly distributed reflecting and/or luminescent particles as being suitable or unsuitable for the authentication process. When referring to classifying particles as being suitable or unsuitable for the authentication process, it should be understood that this does not exclude

further classes (e.g. intermediate suitability or a "tentative" group) but merely implies that the particles are classified in at least two groups one of which represents a class of particles having a higher suitability for the authentication process than the other.

[0059] In some examples, classifying may include identifying particles from the plurality of reflective and/or luminescent particles on the plurality of reference images. Said identifying step can be performed in analogy to the identifying 710 step elucidated further above with respect to a single reference image. In particular, particles from the plurality of randomly distributed reflecting and/or luminescent particles may be classified to be suitable for the authentication process based on the identifying step. In some examples, each of the particles from the plurality of reflective and/or luminescent particles may be classified in this way.

[0060] In some examples, particles from the plurality of randomly distributed reflecting and/or luminescent particles may be classified to be suitable if said particles are identified on each of the plurality of reference images or if said particles are identified in more than a predefined percentage of the plurality of reference images. Again, each of the particles from the plurality of randomly distributed reflecting and/or luminescent particles may be classified in this way. Suitable a predefined percentage of reference images are not particularly limited and may include e.g. in more than about 40%, or in more than about 60%, or in more than about 80% of reference images.

[0061] In some embodiments, the digital compensation 700 of the deviations may comprise identifying 760 at least one reference unmarked area in the one or more reference images and setting 770 a reference value based on the color, color intensity and/or brightness to a value of the unmarked area and identifying 780 the at least one reference unmarked area in the one or more authentication images. The digital compensation 700 may further comprise computing 750 a projection image by adjusting 790 the color, color intensity and/or brightness of the at least one authentication image and/or the at least one reference image to match one another within the at least one reference unmarked area. The afore described method may allow digitally compensating 700 color, color intensity and/or brightness differences without the use of orientation marks.

[0062] As depicted in Figure 9, the recording 400 on a mobile device the one or more authentication images may comprise instructing 430 a user to align a camera comprised within the mobile device. Instructing the user to align the camera comprised within the mobile device may aid in reducing differences in the recording angle. As result, the need for digital compensation 700 may be reduced. As methods for digital compensation 700 may be imperfect, a higher degree of digital compensation may also require setting higher threshold values for determining 600 whether the product to be authenticated is authentic, as to prevent an excess number of falsen-

egatives. However, higher threshold values may also lead to higher false-positive rates.

[0063] In some embodiments, instructing 430 the user may comprise identifying 410 the one or more authenticating marks on a product to be identified. Further instructing 430 the user may comprise displaying 440 a current visual image recorded by the camera and displaying 450 the one or more authenticating marks previously identified 410 within the at least one reference image on a display comprised within the mobile device as an overlay with the displayed 440 current visual image. Instructing 430 the user may optionally comprise signaling 460 to the user to record 400 the one or more authenticating images when one or more authenticating marks within the current visual image recorded by the camera sufficiently matches the one or more authenticating marks previously identified 210 within the at least one reference images. Alternatively, instructing 430 the user may optionally comprise automatically recording 470 the one or more authenticating images when one or more authenticating marks within the current visual image recorded by the camera sufficiently matches the one or more authenticating marks previously identified 410 within the at least one reference images. The authenticating mark may also be only partly displayed 450, for example, only the outlines as sketched in Figure 12 may be overlaid with the current displayed 440 visual image.

[0064] In some embodiments, instructing 430 the user may comprise identifying 1410 the orientation mark on a product to be identified. Further instructing 430 the user may comprise displaying 1440 a current visual image recorded by the camera and displaying 1450 the orientation mark previously identified 1410 within the at least one reference image on a display comprised within the mobile device as an overlay with the displayed 1440 current visual image. Instructing 430 the user may further optionally comprise signaling 460 to the user to record 400 the one or more authenticating images when one or more authenticating marks within the current visual image recorded by the camera sufficiently matches the one or more authenticating marks previously identified 210 within the at least one reference images. Alternatively, instructing 430 the user may optionally comprise automatically recording 470 the one or more authenticating images when one or more authenticating marks within the current visual image recorded by the camera sufficiently matches the one or more authenticating marks previously identified 410 within the at least one reference images. Similar to the embodiment described above, only parts of the orientation mark may be displayed 1450, e.g. only the outlines, to instruct 430 the user.

[0065] In some embodiments, the authentication mark may have a width between about 0.1 mm to about 5 mm, more specifically between about 0.3 to 3 mm and in particular between about 0.5 mm to about 2 mm. The widths stated above may be deposited by writing instruments. Further, the widths stated above may not lead to a visual distraction on the authentic product after the marking

100.

[0066] In some embodiments, the method may comprise applying the authentication mark to a porous substrate, in particular a paper. In other words, the authentic product may comprise a porous material. Pores within the porous substrate may absorb the ink, which may influence the formation of the unique surface textures. More specifically, the pores, in particular in paper, may be random, which may lead to absorption of the ink into the pores in a random pattern which may lead to the formation of unique surface textures. For example, the pores may appear darker or have increased color intensity after absorbing the ink compared to the surrounding area.

[0067] In some embodiments, the method may comprise applying the authentication mark to a coated surface, more specifically a polymer coated surface, wherein the contact angle between the ink and the coated surface may be between about 45° to 180°, more specifically between about 90° to about 135° and in particular between about 100° to about 125°. The contact angles stated above may lead to an increase in the formation of unique surface textures and/or an increase in the size of the unique surface textures. The contact angles stated above may lead to random coagulation of the ink on the authentic product.

[0068] In some embodiments, the density of the particles in the ink may be between about 10,000 to about 10,000,000 particles/cm³, more specifically between about 100,000 to about 5,000,000 particles/cm³ and in particular between about 500,000 to about 900,000 particles/cm³.

[0069] In some embodiments, the density of the particles in the authentication mark may be between about 1 to about 100 particles/cm², more specifically between about 20 to about 80 particles/cm² and in particular between about 30 to about 50 particles/cm². The density of the particles in the authentication to the density of the particles after the ink has been deposited on a writing substrate, in particular a cellulose paper using a ballpoint pen, in particular a parker GEL ballpoint pen Refill.

[0070] The ink may in some embodiments, also be removable, e.g. water-soluble, to allow subsequent removal from the authentic product. In some embodiments, the ink may be permanent to prevent removal from the authentic product.

[0071] Although specific embodiments of the present disclosure have been disclosed for illustrative purposes, those skilled in the art will appreciate that various modifications and alterations are possible, without departing from the spirit of the present disclosure. It is also to be understood that such modifications and alterations are incorporated in the scope of the present disclosure and the accompanying claims.

[0072] The present disclosure further relates to following list of aspects, the contents of which are intended to be freely combinable with other parts of the aforementioned disclosure.

1. A method for an optical product authentication, the method comprising:

- manually marking (100) an authentic product with one or more authenticating marks with a hand-held writing instrument dispensing an ink;
- recording (200) on a mobile device one or more reference images including the one or more authenticating mark;
- optionally transmitting (300) the one or more reference images to a server;
- recording (400) on a mobile device one or more authentication images of a product to be authenticated including one or more authenticating marks;
- comparing (500) the one or more authentication images with the one or more reference images, wherein comparing (500) comprises:

- a) identifying (510) one or more unique surface textures of the one or more authenticating marks within the one or more reference images and within the one or more authentication images, wherein the one or more unique surface textures comprises irregularities in shape, color, color intensity and/or brightness which are caused by manually marking (100) an authentic product with one or more authenticating marks, and
- b) comparing (520) one or more of the identified unique surface textures of the one or more reference images to the one or more identified unique surface textures of the one or more authentication images;

- indicating (610) a positive authentication if the one or more unique surface textures of the authenticating mark sufficiently match in the least one authentication images and the at least one reference images; or
- indicating (620) a negative authentication if the more unique surface textures of the authenticating mark do not sufficiently match in the least one authentication images and the at least one reference images.

2. The method according to aspect 1, wherein the method comprises identifying (210) the one or more authenticating marks in the one or more reference images and identifying (410) the at least one authenticating mark in the one or more authentication images.

3. The method according to any preceding aspect, wherein the method comprises:

- identifying (220) at least one edge region of the

- one or more authenticating marks in the one or more reference images;
- identifying (420) at least one edge region of the one or more authenticating marks in the one or more authenticating images; and
 - comparing (520) the one or more unique surface textures in the at least one edge region of the reference image with the one or more unique surface textures in the at least one edge region of the authenticating image.
4. The method according to any preceding aspect, wherein identifying (510) the one or more unique surface textures of the one or more authenticating marks comprises determining (530) coordinates representing relative positions of the color, color intensity and/or brightness.
5. The method according to aspect 4, wherein determining (530) the coordinates representing the relative positions comprises:
- placing (540) a grid over the one or more reference images and/or the one or more authentication images to form a first plurality of boxes;
 - determining (550) the relative position and the color, color intensity and/or brightness of a second plurality of boxes;
- or determining (560) the relative position and the color, color intensity and/or brightness of a second plurality of boxes disposed within the one or more authenticating marks.
6. The method according to aspect 5, wherein the second plurality of boxes is the same as the first plurality of boxes.
7. The method according to any preceding aspect, wherein the one or more reference images and/or the one or more authentication images are high-resolution images.
8. The method according to any one of aspects 5 to 7, wherein the width of each box of the first and/or second plurality of boxes is between 5 μm to about 100 μm , more specifically between about 10 μm to about 50 μm and in particular between about 20 μm to about 30 μm .
9. The method according to any one of aspects 5 to 8, wherein the length of each box of the first and/or second plurality of boxes is between 5 μm to about 100 μm , more specifically between about 10 μm to about 50 μm and in particular between about 20 μm to about 30 μm .
10. The method according to any one of aspects 5

to 7 or 9, wherein the width of each box of the first and/or second plurality of boxes is between 0.5 μm to about 10 μm , more specifically between about 1 μm to about 5 μm and in particular between about 2 μm to about 3 μm .

11. The method according to any one of aspects 5 to 8 or 10, wherein the length of each box of the first and/or second plurality of boxes is between 0.5 μm to about 10 μm , more specifically between about 1 μm to about 5 μm and in particular between about 2 μm to about 3 μm .

12. The method according to any one of aspects 5 to 7, wherein an area of each box of the first and/or second plurality of boxes corresponds to an area of a pixel of the one or more reference images and/or the one or more authentication images.

13. The method according to any one of aspects 5 to 12, wherein the color of each box or coordinate is identified as the box's average or the coordinate's a*-value and b*-value in the CIELAB color space or h°-value in CIELCh color space.

14. The method according to any one of aspects 5 to 13, wherein the brightness of each box or coordinate is identified as the box's average or the coordinate's L*-value in the CIELAB color space.

15. The method according to any one of aspects 5 to 14, wherein the color intensity of each box or coordinate is identified as the box's average or the coordinate's C*-value in the CIELCh color space.

16. The method according to any preceding aspect, wherein the one or more authenticating mark comprises at least two edges, wherein identifying (510) the one or more unique surface textures comprises determining (1530) a plurality of distances between the at least two edges.

17. The method according to aspect 16, wherein determining (1530) the plurality of distances between the at least two edges comprises identifying (1540) the at least two edges, wherein identifying (1540) the at least two edges comprises:

- identifying (1550) an unmarked area and setting (1555) a threshold value and/or threshold range based on the color, color intensity and/or brightness to a value of the unmarked area;
- identifying (1560) marked coordinates representing the relative positions of the color, color intensity and/or brightness deviating from the unmarked area's threshold value and/or threshold range;
- identifying (1570) edge coordinates represent-

ing the relative positions which neighbor coordinates of the unmarked area and marked coordinates;

- identifying (1580) inner marked coordinates representing the relative position which neighbor only marked coordinates. 5

18. The method according to aspect 16 or 17, wherein determining (1530) the plurality of distances between the at least two edges comprises determining (1590) a plurality of shortest straight lines connecting two of the edge coordinates while crossing at least one marked coordinate. 10

19. The method according to any preceding aspect, wherein identifying (510) the one or more unique surface textures comprises determining (2530) a plurality of relative coordinates of a subset of coordinates. 15

20. The method according to aspect 19, wherein determining (2530) the plurality of relative coordinates of the subset of coordinates comprises: 20

- identifying (2540) the subset of coordinates, wherein the subset of coordinates comprises a plurality coordinates exhibiting the highest brightness and/or color intensity and/or the lowest brightness and/or color intensity; and 25

determining (2550) one or more distances and/or one or more angles between the plurality of coordinates as the plurality of relative coordinates. 30

21. The method according to any preceding aspect, wherein comparing (520) further includes calculating (550) a measure of deviation between the one or more authentication images and the one or more reference images. 35

22. The method according to any preceding aspect, wherein the method comprises determining (600) whether the product to be authenticated is the authentic product or a counterfeit product, wherein determining (600) whether the product to be authenticated is the authentic product or a counterfeit product comprises classifying (610) the product to be authenticated as authentic if the calculated (550) measure of deviation is smaller than a predetermined threshold value and otherwise classifying (620) the product to be authenticated as counterfeit, or classifying (610) the product to be authenticated as authentic if the calculated (550) measure of deviation is larger than a predetermined threshold value and otherwise classifying (620) the product to be authenticated as counterfeit. 40 45 50 55

23. The method according to any preceding aspect,

wherein the method comprises digital compensation (700), wherein the digital compensation (700) comprises compensating deviations between the one or more authentication images and the one or more reference images.

24. The method according to aspect 23, wherein the digital compensation (700) of the deviations comprises:

- identifying (710) coordinates of a plurality of reflective and/or luminescent particles disposed within the authenticating marks within the one or more reference images;
- identifying (720) coordinates of a plurality of reflective and/or luminescent particles disposed within the authenticating marks within the one or more authentication images;
- determining (730) a deviation between the one or more reference images and in the one or more authentication images based on a digital image analysis, wherein said deviation is associated with a difference between the recording position relative to the plurality of reflective and/or luminescent particles in the one or more reference images and the recording position relative to the plurality of reflective and/or luminescent particles in the one or more authentication images;
- computing (750) a projection image by projecting (740) the one or more authentication images on the one or more reference images or the one or more reference image on the one or more authentication images based on the determined (730) deviation;
- comparing (500) the computed projection image with the one or more authentication images or the one or more reference images. 25 30 35 40

25. The method according to aspect 23 or 24, wherein the digital compensation (700) of the deviations comprises:

- identifying (760) at least one reference unmarked area in the one or more reference images and setting (770) a reference value based on the color, color intensity and/or brightness to a value of the unmarked area;
- identifying (780) the at least one reference unmarked area in the one or more authentication images;
- computing (750) a projection image by adjusting (790) the color, color intensity and/or brightness of the at least one authentication image and/or the at least one reference image to match one another within the at least one reference unmarked area. 45 50 55

26. The method according to any preceding aspect,

wherein the method comprises applying (1100) an orientation mark to the authentic product.

27. The method according to aspect 26, wherein the digital compensation (700) of the deviations comprises:

- identifying (1200) the orientation mark in the one or more reference images;
- identifying (1400) the orientation mark in the one or more authentication images;
- determining (1500) a deviation between the one or more reference images and in the one or more authentication images based on a digital image analysis, wherein said deviation is associated with a difference between the recording position relative to the one or more orientation marks in the one or more reference images and the recording position relative to the one or more authentication marks in the one or more authentication images;
- computing (750) a projection image by projecting the one or more authentication images on the one or more reference images or the one or more reference image on the one or more authentication images based on the determined (1500) deviation;
- comparing (500) the computed projection image with the one or more authentication images or the one or more reference images.

28. The method according to any preceding aspect, wherein the recording (400) on a mobile device the one or more authentication images comprises instructing (430) a user to align a camera comprised within the mobile device.

29. The method according to aspect 28, wherein instructing (430) the user comprises:

- identifying (410) the one or more authenticating marks on a product to be identified;
- displaying (440) a current visual image recorded by the camera;
- displaying (450) the one or more authenticating marks previously identified (410) within the at least one reference image on a display comprised within the mobile device as an overlay with the displayed (440) current visual image;
- (optionally) signaling (460) to the user to record (400) the one or more authenticating images when one or more authenticating marks within the current visual image recorded by the camera sufficiently matches the one or more authenticating marks previously identified (210) within the at least one reference images; or,
- (optionally) automatically recording (470) the one or more authenticating images when one or more authenticating marks within the current

visual image recorded by the camera sufficiently matches the one or more authenticating marks previously identified (410) within the at least one reference images.

30. The method according to aspect 28 or 29, wherein instructing (430) the user comprises:

- identifying (1410) the orientation mark on a product to be identified;
- displaying (1440) a current visual image recorded by the camera;
- displaying (1450) the orientation mark previously identified (1410) within the at least one reference image on a display comprised within the mobile device as an overlay with the displayed (1440) current visual image;
- (optionally) signaling (460) to the user to record (400) the one or more authenticating images when one or more authenticating marks within the current visual image recorded by the camera sufficiently matches the one or more authenticating marks previously identified (210) within the at least one reference images; or,
- (optionally) automatically recording (470) the one or more authenticating images when one or more authenticating marks within the current visual image recorded by the camera sufficiently matches the one or more authenticating marks previously identified (410) within the at least one reference images.

31. The method according to any preceding aspect, wherein the authentication mark has a width between about 0.1 mm to about 5 mm, more specifically between about 0.3 to 3 mm and in particular between about 0.5 mm to about 2 mm.

32. The method according to any preceding aspect, wherein the method comprises applying the authentication mark to a porous substrate, in particular a paper.

33. The method according to any preceding aspect, wherein the method comprises applying the authentication mark to a coated surface, more specifically a polymer coated surface, wherein the contact angle between the ink and the coated surface is between about 45° to 180°, more specifically between about 90° to about 135° and in particular between about 100° to about 125°.

34. The method according to any preceding aspect, wherein the density of the particles in the ink is between about 1 to about 100 particles/cm², more specifically between about 20 to about 80 particles/cm² and in particular between about 30 to about 50 particles/cm².

Claims

1. A method for an optical product authentication, the method comprising:

- manually marking (100) an authentic product with one or more authenticating marks with a hand-held writing instrument dispensing an ink;
 - recording (200) on a mobile device one or more reference images including the one or more authenticating mark;
 - optionally transmitting (300) the one or more reference images to a server;
 - recording (400) on a mobile device one or more authentication images of a product to be authenticated including one or more authenticating marks;
 - comparing (500) the one or more authentication images with the one or more reference images, wherein comparing (500) comprises:

a) identifying (510) one or more unique surface textures of the one or more authenticating marks within the one or more reference images and within the one or more authentication images, wherein the one or more unique surface textures comprises irregularities in shape, color, color intensity and/or brightness which are caused by manually marking (100) an authentic product with one or more authenticating marks, and
 b) comparing (520) one or more of the identified unique surface textures of the one or more reference images to the one or more identified unique surface textures of the one or more authentication images;

- indicating (610) a positive authentication if the one or more unique surface textures of the authenticating mark sufficiently match in the least one authentication images and the at least one reference images; or
 - indicating (620) a negative authentication if the more unique surface textures of the authenticating mark do not sufficiently match in the least one authentication images and the at least one reference images.

2. The method according to any preceding claim, wherein the method comprises identifying (210) the one or more authenticating marks in the one or more reference images and identifying (410) the at least one authenticating mark in the one or more authentication images.
 3. The method according to claim 1, wherein the method comprises:

- identifying (220) at least one edge region of the one or more authenticating marks in the one or more reference images;
 - identifying (420) at least one edge region of the one or more authenticating marks in the one or more authenticating images; and
 - comparing (520) the one or more unique surface textures in the at least one edge region of the reference image with the one or more unique surface textures in the at least one edge region of the authenticating image.

4. The method according to any preceding claim, wherein identifying (510) the one or more unique surface textures of the one or more authenticating marks comprises determining (530) coordinates representing relative positions of the color, color intensity and/or brightness.

5. The method according to claim 3, wherein determining (530) the coordinates representing the relative positions comprises:

- placing (540) a grid over the one or more reference images and/or the one or more authentication images to form a first plurality of boxes;
 - determining (550) the relative position and the color, color intensity and/or brightness of a second plurality of boxes;

or determining (560) the relative position and the color, color intensity and/or brightness of a second plurality of boxes disposed within the one or more authenticating marks.

6. The method according to any preceding claim, wherein the one or more authenticating mark comprises at least two edges, wherein identifying (510) the one or more unique surface textures comprises determining (1530) a plurality of distances between the at least two edges.

7. The method according to claim 6, wherein determining (1530) the plurality of distances between the at least two edges comprises identifying (1540) the at least two edges, wherein identifying (1540) the at least two edges comprises:

- identifying (1550) an unmarked area and setting (1555) a threshold value and/or threshold range based on the color, color intensity and/or brightness to a value of the unmarked area;
 - identifying (1560) marked coordinates representing the relative positions of the color, color intensity and/or brightness deviating from the unmarked area's threshold value and/or threshold range;
 - identifying (1570) edge coordinates represent-

- ing the relative positions which neighbor coordinates of the unmarked area and marked coordinates;
- identifying (1580) inner marked coordinates representing the relative position which neighbor only marked coordinates.
- 5
8. The method according to claim 6 or 7, wherein determining (1530) the plurality of distances between the at least two edges comprises determining (1590) a plurality of shortest straight lines connecting two of the edge coordinates while crossing at least one marked coordinate.
- 10
9. The method according to any preceding claim, wherein identifying (510) the one or more unique surface textures comprises determining (2530) a plurality of relative coordinates of a subset of coordinates.
- 15
10. The method according to claim 9, wherein determining (2530) the plurality of relative coordinates of the subset of coordinates comprises:
- identifying (2540) the subset of coordinates, wherein the subset of coordinates comprises a plurality coordinates exhibiting the highest brightness and/or color intensity and/or the lowest brightness and/or color intensity; and
- 20
- determining (2550) one or more distances and/or one or more angles between the plurality of coordinates as the plurality of relative coordinates.
- 25
11. The method according to any preceding claim, wherein comparing (520) further includes calculating (550) a measure of deviation between the one or more authentication images and the one or more reference images.
- 30
12. The method according to claim 11, wherein the method comprises determining (600) whether the product to be authenticated is the authentic product or a counterfeit product, wherein determining (600) whether the product to be authenticated is the authentic product or a counterfeit product comprises classifying (610) the product to be authenticated as authentic if the calculated (550) measure of deviation is smaller than a predetermined threshold value and otherwise classifying (620) the product to be authenticated as counterfeit, or classifying (610) the product to be authenticated as authentic if the calculated (550) measure of deviation is larger than a predetermined threshold value and otherwise classifying (620) the product to be authenticated as counterfeit.
- 35
- 40
- 45
- 50
- 55
- (700), wherein the digital compensation (700) comprises compensating deviations between the one or more authentication images and the one or more reference images.
14. The method according to claim 13, wherein the digital compensation (700) of the deviations comprises:
- identifying (760) at least one reference unmarked area in the one or more reference images and setting (770) a reference value based on the color, color intensity and/or brightness to a value of the unmarked area;
 - identifying (780) the at least one reference unmarked area in the one or more authentication images;
 - computing (750) a projection image by adjusting (790) the color, color intensity and/or brightness of the at least one authentication image and/or the at least one reference image to match one another within the at least one reference unmarked area.
15. The method according to any preceding claim, wherein the recording (400) on a mobile device the one or more authentication images comprises instructing (430) a user to align a camera comprised within the mobile device.

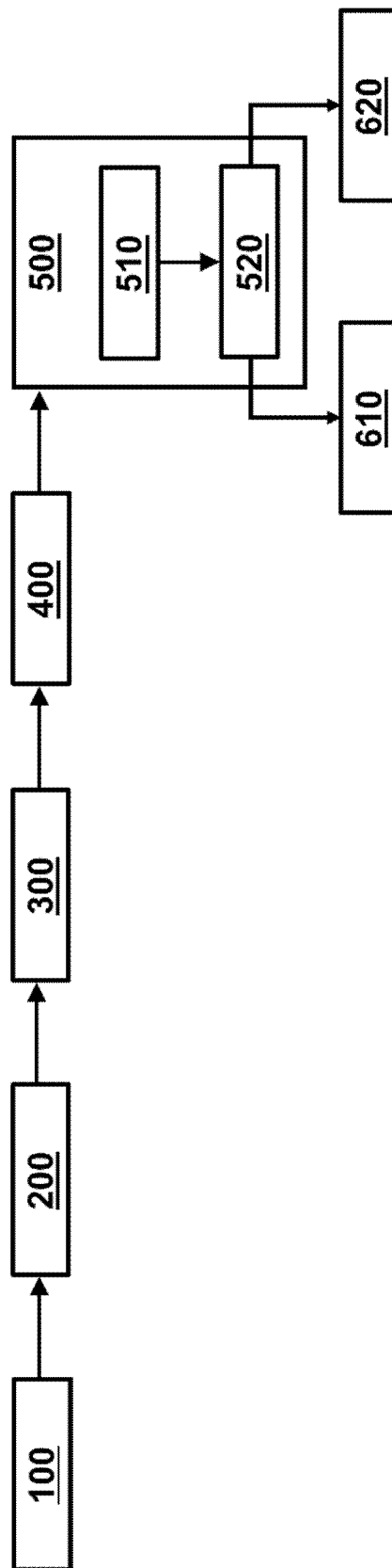


Figure 1

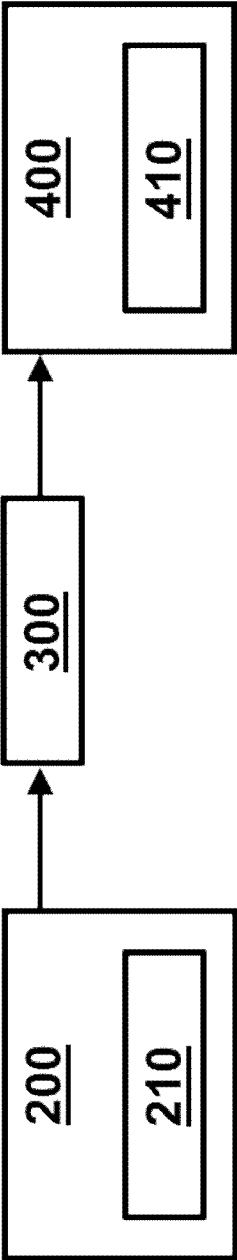


Figure 2A

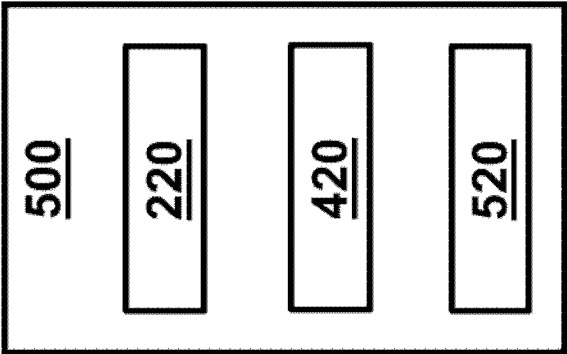


Figure 2B

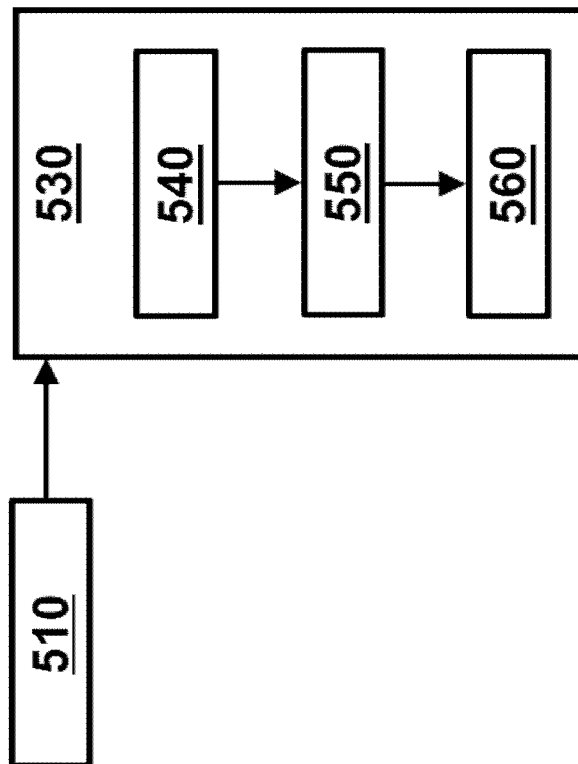


Figure 3

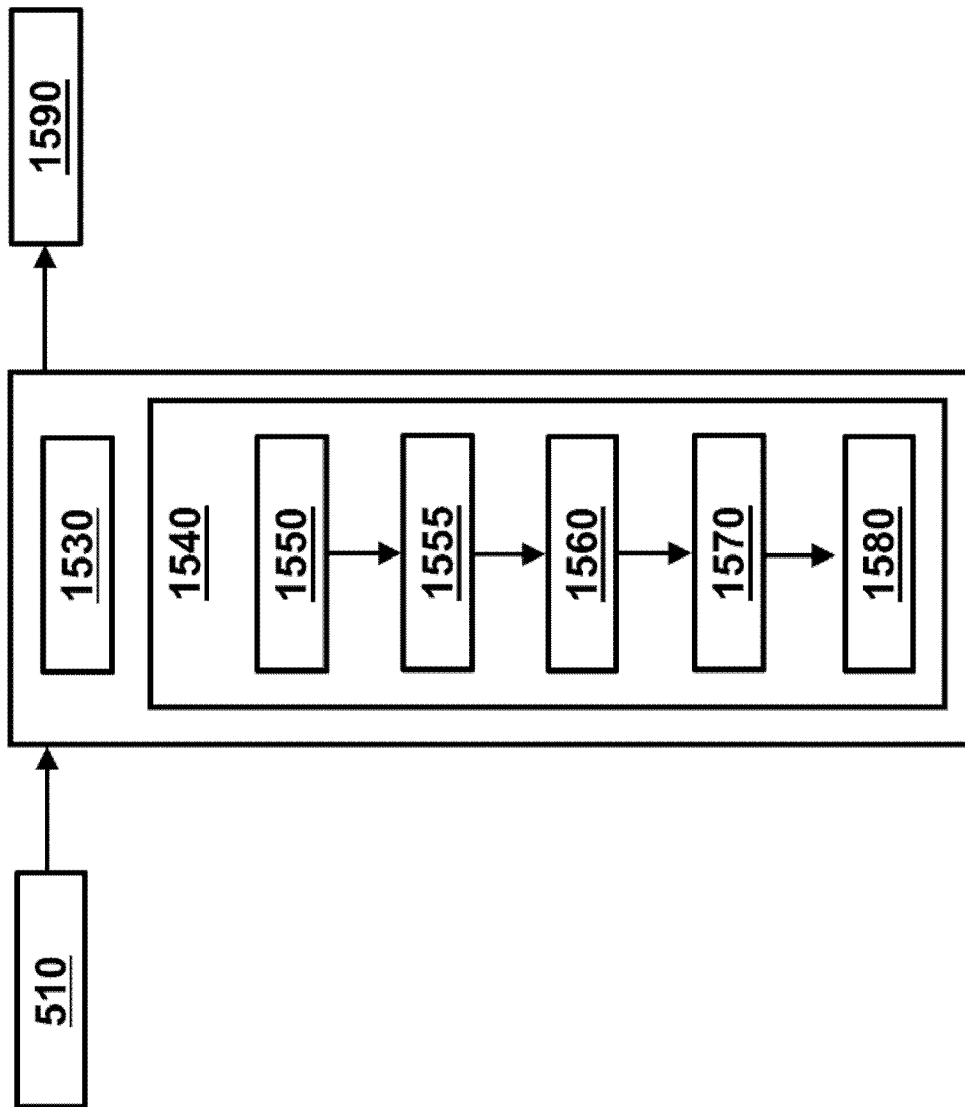


Figure 4

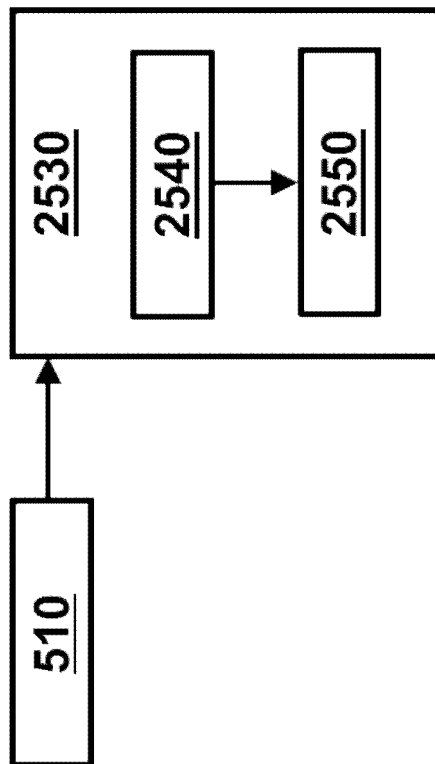


Figure 5

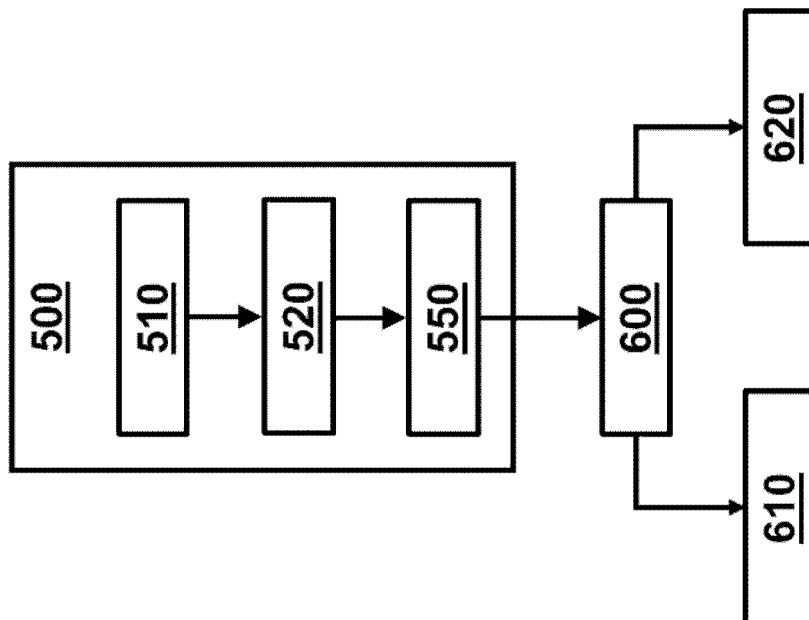


Figure 6

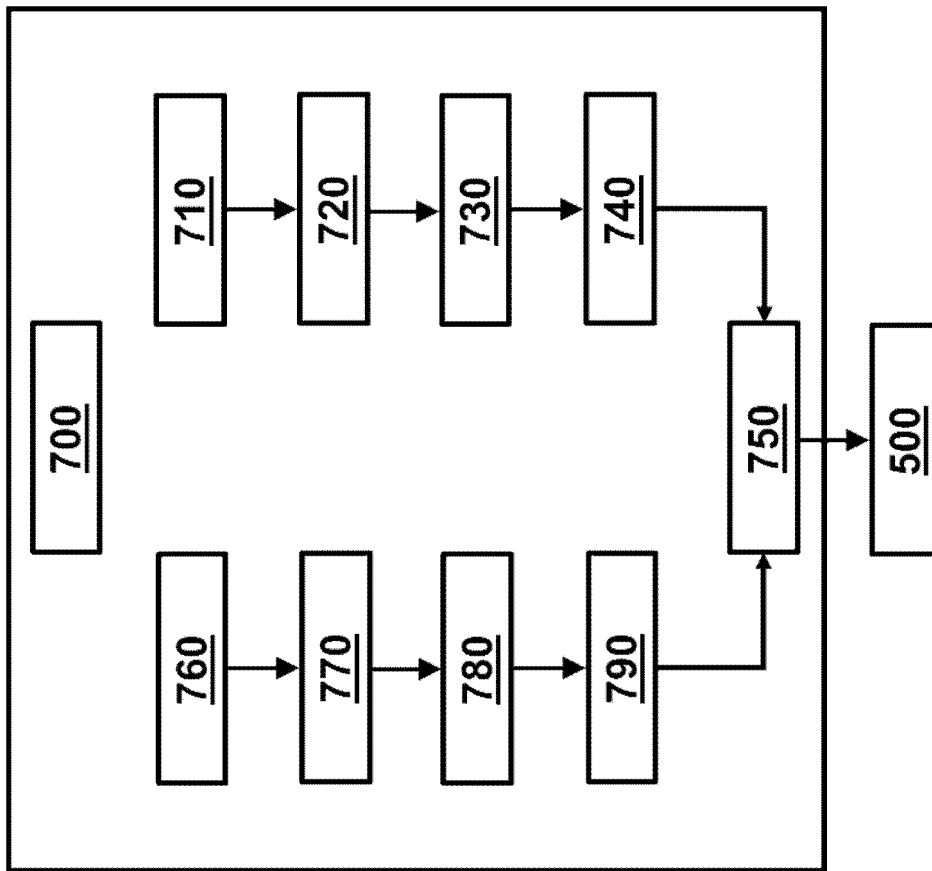


Figure 7

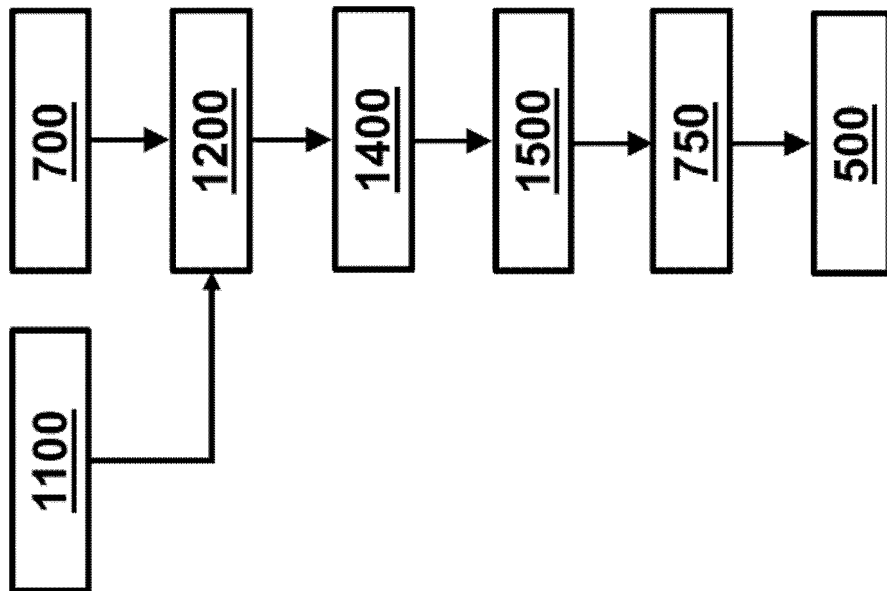


Figure 8

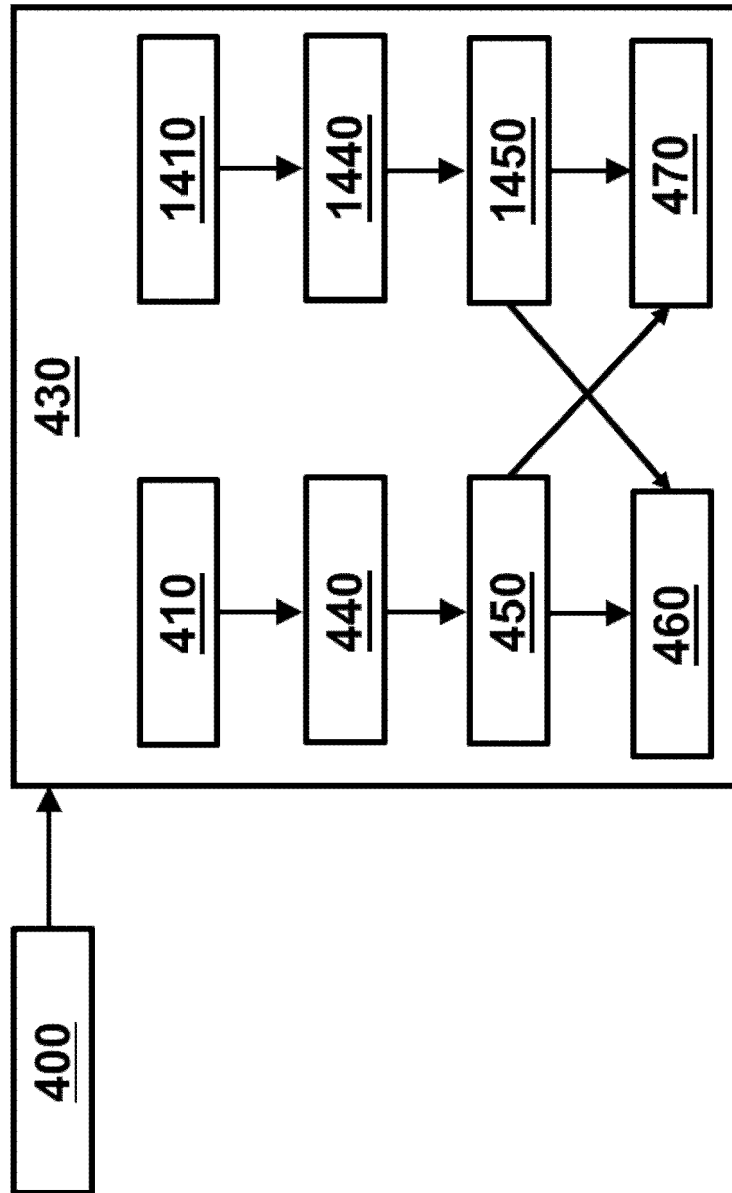


Figure 9

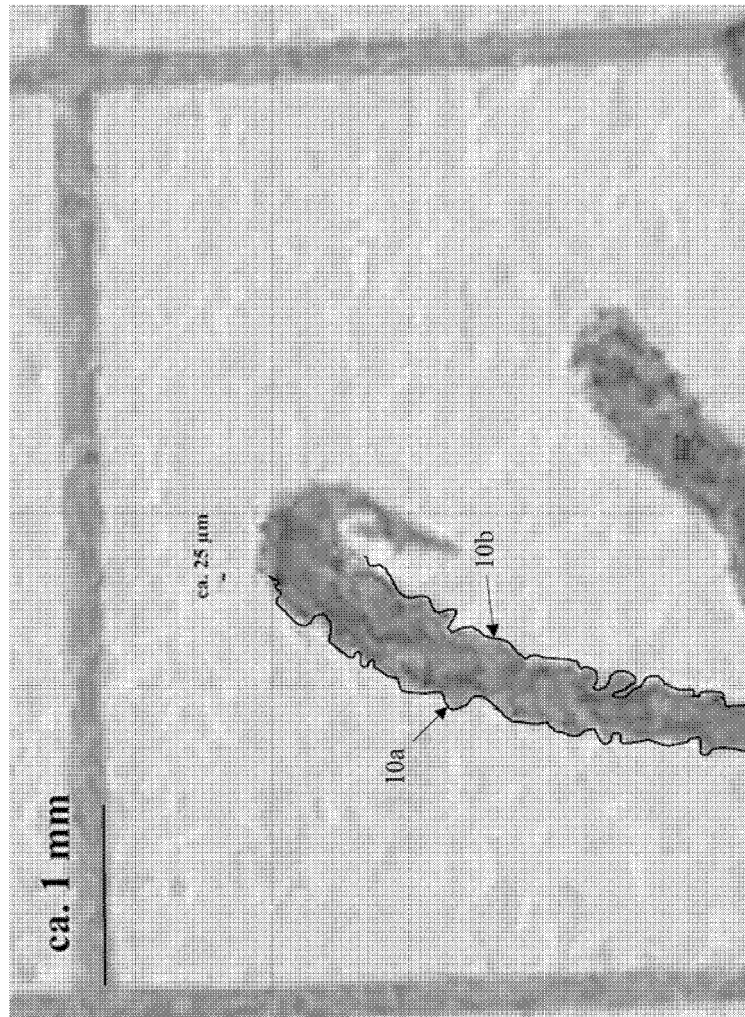


Figure 10

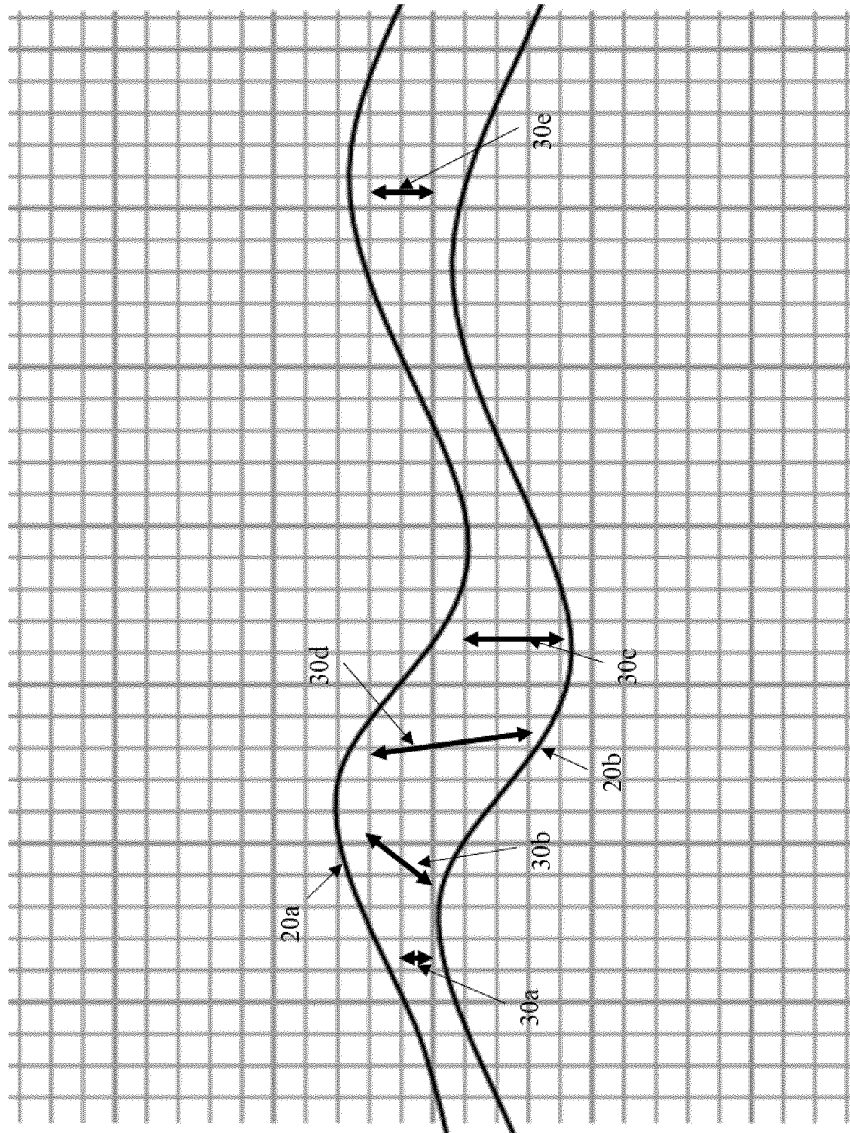


Figure 11



EUROPEAN SEARCH REPORT

Application Number

EP 22 17 2375

5

10

15

20

25

30

35

40

45

50

55

1

EPO FORM 1503 03.82 (P04C01)

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 2014/205153 A1 (SHARMA ASHLESH [US] ET AL) 24 July 2014 (2014-07-24) * paragraphs [0007] - [0018], [0023] * * paragraphs [0056] - [0094] * * claim 124 * * figures 1-4 *	1-15	INV. G07D7/2033 G07D7/20
X	US 2014/168690 A1 (COWBURN RUSSELL PAUL [GB]) 19 June 2014 (2014-06-19) * paragraphs [0066] - [0138] * * figures 1-19 *	1-15	
A	US 2007/074030 A1 (QUINE DOUGLAS B [US]) 29 March 2007 (2007-03-29) * paragraphs [0003] - [0010] * * paragraphs [0020] - [0052] * * figures 1-8 *	1-15	
			TECHNICAL FIELDS SEARCHED (IPC)
			G07D
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 14 October 2022	Examiner Bauer, Sebastian
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	

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 22 17 2375

5

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

14-10-2022

10

15

20

25

30

35

40

45

50

55

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
US 2014205153 A1	24-07-2014	CN	103502811 A		08-01-2014
		CN	105303164 A		03-02-2016
		EP	2686676 A2		22-01-2014
		JP	6161543 B2		12-07-2017
		JP	2014511993 A		19-05-2014
		KR	20140018296 A		12-02-2014
		US	2014205153 A1		24-07-2014
		WO	2012126008 A2		20-09-2012

US 2014168690 A1	19-06-2014	AR	048089 A1		29-03-2006
		AT	433164 T		15-06-2009
		AU	2005220383 A1		22-09-2005
		BR	PI0508635 A		07-08-2007
		CA	2559271 A1		22-09-2005
		CN	1969284 A		23-05-2007
		EP	1730665 A1		13-12-2006
		EP	2081130 A2		22-07-2009
		HK	1086795 A1		29-09-2006
		HK	1139901 A1		30-09-2010
		IL	177966 A		30-11-2010
		JP	5148996 B2		20-02-2013
		JP	5283744 B2		04-09-2013
		JP	5654541 B2		14-01-2015
		JP	2007528812 A		18-10-2007
		JP	2012070396 A		05-04-2012
		JP	2013034238 A		14-02-2013
		KR	20070024510 A		02-03-2007
		MY	142465 A		30-11-2010
		RU	2380750 C2		27-01-2010
		TW	200622926 A		01-07-2006
		US	2008002243 A1		03-01-2008
		US	2012170069 A1		05-07-2012
		US	2014168690 A1		19-06-2014
WO	2005088517 A1		22-09-2005		

US 2007074030 A1	29-03-2007	NONE			

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- EP 2318286 B1 [0036]