

Identification and Authentication using Polymeric Liquid Crystal Material Markings

Field of the Invention

5 The present invention relates to a machine readable marking for the recognition, identification and authentication of individual items. The marking is made of liquid crystal material, which is applied to a substrate by known variable information printing techniques. The marking is detectable
10 and/or identifiable by passive detecting means, e.g. optical filters under unpolarized (ambient) light, as well as by illumination with polarized light. The marking is applied in the form of indicia, such as a one- or two-dimensional bar code, a matrix code, or the like.

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Background of the Invention

"Track and Trace" systems are currently used in different fields of industry. Many industries suffer from counterfeit or diverted products, in particular in the field of mass-produced
20 items such as beverages, perfumes, pharmaceutical drugs, cigarettes, CDs/DVDs, as well as other kind of consumables.

Counterfeiting and market diversion are facilitated if the mass products are handled on a lot base, rather than on an
25 individual item base. Counterfeit or diverted products are in such case easily introduced into the supply chain. Producers and retailers would like to be in a position to distinguish their original products from such counterfeit or diverted (parallel imported) products at the level of the individual
30 unit which can be sold.

The underlying technical problem has been addressed in the art through an individual marking of each sellable item introduced into the supply chain. The markings of the prior art were

chosen in such a way that they were not susceptible to photocopying, i.e. preferably covert markings were used, which are not visible to the unaided eye or the photocopying machine.

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A "Covert" marking, in the context of the present invention, is any marking or security element, which cannot be authenticated by the unaided eye, but which, for authentication, depends on a detecting or reading device of
10 any kind, such as an optical filter or an electronic authentication equipment.

An "Overt" marking, in the context of the present invention, is any marking or security element, which, for authentication,
15 does not depend on a detecting or reading device; i.e. which can be authenticated by the unaided eye.

"Color" in the context of the present invention is used to designate any spectrally selective return of light
20 (electromagnetic radiation) from an illuminated object, be it in the visible, the infrared or in the UV range of the electromagnetic spectrum (i.e. in the whole wavelength range from 200nm to 2500nm).

25 The term "visible" is used to indicate that a property can be revealed by the unaided eye; "detectable" is used for a property that can be revealed by an optical instrument, though not necessarily by the unaided eye, and "invisible" is used for a property that cannot be detected by the unaided eye. In
30 particular, the term "visible color" means a spectrally selective return of light in the wavelength range from 400nm to 700nm, which is detectable by the unaided eye.

In the context of the present invention, the terms material and composition are interchangeable.

A first type of individual markings, useful to prevent
5 counterfeit and diversion, is disclosed in US 5,569,317, US
5,502,304, US 5,542,971 and US 5,525,798. According to these
documents, a bar code is applied onto the item, using an ink
which is not detectable under light of the visible spectrum
(400-700nm wavelength) but which becomes visible when
10 illuminated with light of the UV spectrum (200-380nm
wavelength).

A second type of individual markings is disclosed in US
5,611,958 and US 5,766,324. According to these documents, a
15 marking is applied onto a commercial good, using an ink which
is not detectable in the visible spectrum, but which can be
detected through illumination with light of the infrared
spectrum (800-1600nm wavelength).

20 Yet another type of individual markings, applied through an
ink, is disclosed in US 5,360,628 and US 6,612,494. This
marking needs to be illuminated jointly with UV- and IR-light
to be revealed.

25 Still another type of individual marking relies on inks
comprising up-converting phosphors such as described in US
5,698,397.

All of the markings mentioned in the cited prior art are
30 covert markings, which are completely invisible to the unaided
human eye. The reading of such covert markings depends on a
corresponding detecting or reading device, able to detect or
read the marking. This can be a disadvantage at the retail

center or at the point-of-sale, where an appropriate reading device may not always be available.

Overt markings comprising "optically variable" features, e.g. exhibiting viewing-angle dependent color, have been proposed in the art as authentication means for the "person in the street". Among these are the holograms (cf. Rudolf L. van Renesse, "Optical Document Security" 2nd ed., 1998, chapter 10), the optical thin film security devices (idem, chapter 13) and the liquid crystal security devices (idem, chapter 14).

Particularly useful as security devices are the cholesteric liquid crystals. When illuminated with white light, the cholesteric liquid crystal structure reflects light of a determined color, which depends on the material in question and generally varies with the angle of observation and the device temperature. The cholesteric material itself is colorless and the observed color is only due to a physical reflection effect at the cholesteric helical structure adopted at a given temperature by the liquid crystal material. (cf. J.L Fergason, *Molecular Crystals*, Vol. 1, pp. 293-307 (1966)). In particular liquid crystal materials, the cholesteric liquid crystal polymers (CLCPs), the cholesteric helical structure is "frozen" in a determined state through polymerization, and thus rendered temperature-independent.

If the cholesteric liquid crystal material is applied on a dark or black background, its reflection color is highly apparent to the unaided eye, because the light transmitted by the cholesteric material is largely absorbed by the background, so that the residual backscattering from the background does not disturb the perception of the cholesteric material's own reflection. A careful choice of the background

color can thus contribute to the visibility of such an overt marking.

On a clear or white background the reflection color of the
5 cholesteric liquid crystal material is virtually invisible due
to the superposition of the cholesteric material's own
reflection with the strong backscattering from the background.
The cholesteric liquid crystal material can, however, always
be identified with the help of a circular polarization filter
10 because it selectively reflects only one of the two possible
circular polarized light components, in accordance with its
chiral helical structure.

EP-B1-1 381 520 and EP-A1-1 681 586 refer to a birefringent
15 marking and a method of applying the same in the form of a
liquid crystal layer having a non-uniform pattern of regions
of different thickness. The applied liquid crystal coating or
layer may provide for a hidden image on a reflective
substrate, which is invisible when viewed under unpolarized
20 light but rendered visible under polarized light or with the
help of a polarization filter.

US 5,678,863 refers to means for the identification of
documents of value which include a paper or polymer region,
25 said region having a transparent and translucent
characteristic. A liquid crystal material is applied to the
region to produce an optical effect, which differs when viewed
in transmitted and reflected light. The liquid crystal
material is in liquid form at room temperature and must be
30 enclosed in a containing means such as microcapsules, in order
to be used in a printing process such as gravure, roller,
spray or ink-jet printing. The printed liquid crystal region
can be in the form of a pattern, for example a bar code. The

pattern can be verified by visual or machine inspection of the polarization states of the areas having left-handed and right-handed liquid crystal forms.

5 US 5,798,147 refers to coating compositions of polymerizable liquid crystal monomers which can be applied by conventional printing processes, such as letterpress, rotogravure, flexographic, offset, screen, and ink-jet printing. The printing inks can be used to produce markings and security
10 inscriptions which are invisible to the human eye. The markings can be detected by their circular polarization or their angle dependent reflection color.

US 6,899,824 refers to a process for printing or coating a
15 substrate with a multilayer of a liquid-crystalline composition and at least one non-liquid-crystalline coating. The process and the printed substrate are useful for producing a counterfeit-proof marking of articles. Preferred methods for applying such printing or coating are screen printing,
20 planographic printing, flexographic, and letterpress printing.

None of the markings disclosed in the prior art does, however, provide a solution to the technical problem underlying "track & trace" applications, wherein, in addition to a machine-
25 readable individual coding of items with a counterfeit-resistant security marking, an easy authentication of the marking by the unaided eye is required.

"Track & Trace" applications are known in the art for e.g.,
30 postal services, wherein each mail piece is individually marked and followed throughout its delivery chain. Barcodes, such as 1D-barcodes, stacked 1D-barcodes, 2D-barcodes or matrix-codes, are most often used as the marking and

identification means.

No particular effort is devoted to authentication aspects in the case of the said postal markings, given that the mail
5 piece is handled service-internally by the mailing company throughout the entire delivery chain, so that no authentication is needed. Postal "Track & Trace" applications are merely focused on the identification of the mail piece.

10 Authentication aspects are, however, of crucial importance in retail applications, where there is a potential risk of substitution of the original goods by counterfeit or diverted ones. For this reason, "Track & Trace" applications in this field must be combined with at least one security element,
15 able to certify the authenticity of the marked good as an original one.

In the following, "Secure Track & Trace" means the combination of a "Track & Trace" application, which allows for the
20 identification of an individual item, with at least one security element, which additionally allows for the authentication of the said item as being genuine.

Technical problem

25 For "Secure Track & Trace" applications, where a good in open circulation must be marked individually as to its authenticity and identity, and followed throughout its life cycle or for a specific period of time, e.g. for liability reasons, there is a need for a marking which is i) uniquely coded, so as to be
30 identifiable ii) machine-readable, iii) copy (counterfeit) resistant, iv) authenticate-able by eye by a human user, and v) authenticate-able by a machine. For particular applications it is furthermore desirable that part of the marking is

invisible to the unaided human eye.

Summary of the Invention

5 The marking of the present invention, for the secure tracking or tracing of an item or article, comprises a polymeric liquid crystal material having determined optical characteristics, which allow for its authentication and reading by a machine, as well as its authentication by the human eye. The marking is
10 produced on a substrate by a variable information printing process in the form of indicia representing a unique code, which allows for its identification. The marking is further preferably laid out such that part of it is invisible to the unaided human eye.

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The marking of the present invention is applied on items or articles such as value documents, banknotes, passports, identity documents, driving licenses, official permissions, access documents, stamps, tax stamps and banderoles,
20 transportation tickets, event tickets, labels, foils, packaging, spare parts, and consumer goods, which thus carry the marking, either directly - applied to their surface - or indirectly - applied to a label applied to their surface.

25 The polymeric liquid crystal material is preferably of the cholesteric (i.e. twisted nematic) type; for certain applications, nematic (birefringent) liquid crystal material may also be used.

30 The polymeric liquid crystal material of the marking can either be present as a liquid crystal material polymerized on the surface of a substrate, or alternatively consist of pigment flakes of a liquid crystal polymer, comprised in a

coating composition applied on a substrate.

Said substrate can be any type of substrate, woven or non-woven, in particular it can be paper, cardboard, wood, glass,
5 ceramic, metal, plastic, textile, leather, etc.; the substrate may be coated or uncoated, or comprise a sealed or a non-sealed surface.

The polymeric liquid crystal material of the marking
10 preferably comprises further security materials, which are present to increase its resistance towards counterfeiting. These security materials are selected from the group consisting of the inorganic luminescent compounds, the organic luminescent compounds, the IR-absorbers, the magnetic
15 materials, the forensic markers, and combinations thereof.

Said security material can be present as a mere admixture, or, according to the nature of the security material, also as a co-polymerized component of the liquid crystal pigment, of the
20 liquid crystal precursor composition, or of the ink binder. In particular, organic security materials comprising an acrylic or vinylic functionality are easily co-polymerized into a corresponding main polymer. Alternatively, the security material may be grafted, i.e. chemically linked, onto a pre-
25 existing polymer chain.

The substrate, representing the background on which the liquid crystal material is applied, can be of any color; a white background being a preferred option for realizing a marking
30 which is invisible to the unaided eye in the sense that no visible color is observed. A metallic reflecting background is a further preferred option, in particular in the case of a nematic (birefringent) liquid crystal material. The substrate

may in general be selected from the group consisting of reflecting substrates, colored substrates, and transparent substrates.

- 5 For enabling an easy authentication by a human user, it is preferred that at least part of the background on which the liquid crystal material is applied has a contrasting color, such as red, green, blue or black, which, in combination with the liquid crystal marking, allows to perceive a visible color
10 and an angle-dependent color change by the unaided eye.

Said substrate is thus preferably a patterned substrate, comprising at least two differently colored surface areas, each selected from the group of white surface areas, black
15 surface areas, visibly colored surface areas, reflecting surface areas, transparent surface areas and combinations thereof. It is thus evident to the skilled in the art that the substrate surface carrying the liquid crystal material can have two or more colored areas underneath the liquid crystal
20 material.

The substrate surface, on which the liquid crystal material is applied, can furthermore carry indicia, which may be of any form or color, such as a pattern, an image, a logo, a text, a
25 1D- or 2D-barcode or a matrix code, etc. The said indicia can be applied by any method of printing or coating.

The substrate can furthermore carry at least one security element selected from the group of inorganic luminescent
30 compounds, organic luminescent compounds, IR-absorbers, magnetic materials, and forensic markers or combinations thereof. The security element can be present in the form of indicia on the substrate surface or be incorporated (embedded)

in the substrate itself.

The polymeric liquid crystal material is preferably present in the form of indicia, such as a text or a code. Preferred
5 indicia are chosen from the group comprising 1-dimensional, stacked 1-dimensional, and 2-dimensional barcodes. Current barcode symbologies have been disclosed by Bob Williams in "*Understanding Barcoding*", Pira International Ltd., 2004 (ISBN 1 85802 917 1)

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The liquid crystal marking of the present invention is preferably produced by applying a liquid crystal precursor composition to a substrate and hardening the composition in the ordered liquid crystal state. The said precursor
15 composition comprises reactive monomers or oligomers of at least one nematic liquid crystal compound. The reactive monomers or oligomers are preferably UV-cure-able; in this case the applied composition is UV-cured and also comprises a photoinitiator system, as known to the skilled person.

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The ordered liquid crystal state depends upon the presence of a chiral dopant. Nematic liquid crystals without chiral dopant arrange in a molecular texture which is characterized by its birefringence. Nematic precursors are known from EP-A-0 216
25 712, EP-B-0 847 432, and US-B-6,589,445.

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For producing a cholesteric (i.e. twisted nematic) liquid crystal polymer, the said precursor composition must also comprise a chiral dopant. Said dopant may be chosen from the derivatives of isosorbides and isomannides and mixtures thereof according to general formula (I) described below. Isosorbides are known to induce a right helical twist, whereas isomannides are known to induce a left helical twist.

Said dopant induces a helical structure in the nematic liquid crystal compound, characterized by a helical pitch of the order of the wavelength of visible light, leading to light
5 reflection at determined wavelengths, and hence to the appearance of interference color, as well as of angle-dependent color shift. The reflected light from cholesteric liquid crystal phases is circularly polarized (either left-handed or right-handed), according to the rotation sense of
10 the cholesteric helical twist.

The marking of the present invention is obtainable as described in claim 1. In one exemplary embodiment, the liquid crystal precursor composition is first applied to a substrate.
15 The second step involves heating the liquid crystal precursor composition applied onto the substrate to both, evaporate the solvent and promote the desired liquid crystal state. The third step involves hardening the said composition on the substrate in the desired liquid crystal state. However, the
20 skilled artisan will appreciate that the above-mentioned sequence may be modified in any way as will be described further below.

The temperature used to evaporate the solvent and to promote
25 the liquid crystal state depends on the liquid crystal monomer composition. According to the present invention, the temperature is chosen preferably between 55°C and 150°C and more preferably between 55°C and 100°C, most preferably between 60°C and 100°C. The hardening is preferably performed
30 by subjecting the applied composition to irradiation with UV-light, which induces a polymerization of the reactive monomers or oligomers to form a liquid crystal polymer. The molecular ordering of the liquid crystal is thereby retained, i.e. the

nematic or cholesteric texture is fixed in the state which was present during the irradiation. In the case of cholesteric liquid crystal material, the helical pitch, and herewith the optical properties, such as the reflection color and the angle-dependent color shift remain thus fixed.

Another embodiment of the present invention is a marking according to the invention for an item or article, said marking comprising polymeric liquid crystal material having determined optical characteristics wherein said polymeric liquid crystal material produced on the substrate is obtained with a chiral dopant according to general formula (I) disclosed below.

A method for marking an item or article comprises thus the steps of providing a suitable item or article to be marked, and applying at least one polymeric liquid crystal material in the form of indicia representing a unique code by a variable information printing process onto the said item or article. In particular, the unique code represented by the said indicia may be encrypted information, and the method may comprise the step of encrypting the said information.

The said liquid crystal precursor composition can be applied to a substrate by any coating or printing technique. Preferably the composition is applied by a variable information printing process, such as laser printing or ink-jet printing of the continuous or of the drop-on-demand type. Said variable information printing method allows for the unique coding of the marking for each printed item.

For application by ink-jet printing, the composition also comprises an organic solvent, in order to adjust the viscosity value of the composition to be compatible with the chosen printing process, as known to the skilled person.

For application by continuous ink-jet printing, the composition also comprises a conducting agent (salt), which must be soluble in the composition used. Such conducting agent
5 is needed as technical requirement of this printing process, as known to the skilled person.

The composition according to the invention comprises a photoinitiator which must be soluble in the composition used.

10 For example of photoinitiator it can be used α -Hydroxyketone such as 1-Hydroxy-cyclohexyl-phenyl-ketone, a mixture (1:1) 1-Hydroxy-cyclohexyl-phenyl-ketone: benzophenone, 2-Hydroxy-2-methyl-1-phenyl-1-propanone or 2-Hydroxy-1-[4-(2-hydroxyethoxy)phenyl]-2-methyl-1-propanone, Phenylglyoxylate
15 such as methylbenzoylformate or a mixture of oxy-phenyl-acetic acid 2-[2 oxo-2 phenyl-acetoxy-ethoxy]-ethyl ester and oxy-phenyl-acetic 2-[2-hydroxy-ethoxy]-ethyl ester, Benzyldimethyl ketal such as Alpha, alpha-dimethoxy-alpha-phenylacetophenone, α -Aminoketone such as 2-Benzyl-2-(dimethylamino)-1-[4-(4-morpholinyl) phenyl]-1-butanone, 2-Methyl-1-[4-(methylthio) phenyl]-2-(4-morpholinyl)-1-propanone, Phosphine oxide derivatives such as Diphenyl (2,4,6-trimethylbenzoyl)-phosphine oxide or Phosphine oxide, phenyl bis(2,4,6-trimethylbenzoyl) supplied by Ciba, and also thioxanthone
20 derivatives such as Speedcure ITX (CAS 142770-42-1), Speedcure DETX (CAS 82799-44-8), Speedcure CPTX (CAS 5495-84-1-2 or CAS 83846-86-0) supplied by Lambson.

The composition according to the invention could also comprise
30 a silane derivative which must be soluble in the composition used. For example of silane derivatives it can be used vinylsilane derivatives such as vinyltriethoxysilane, vinyltrimethoxysilane, vinyltris(2-methoxyethoxy)silane, 3-

Methacryloxypropyltrimethoxysilane, Octyltriethoxysilane or 3-Glycidyloxypropyl triethoxysilane from Dynasylan ® family supplied by Evonik.

5 In general, the method for authenticating an item or article carrying a marking according to the present invention comprises the steps of a) providing an item or article carrying a marking according to the present invention, b) illuminating the marking on said item or article with at least
10 one quality of light from at least one light source, c) detecting the said marking's optical characteristics through the sensing of light reflected by the marking, d) determining the item's or article's authenticity from the detected optical characteristics of the marking.

15

The marking of the present invention can be authenticated according to a first method by simple visual inspection under ambient light. To this aim, the background, on which the liquid crystal material is applied, must provide sufficient
20 optical contrast, so as to allow the human observer to perceive the reflected color and the color shift of the liquid crystal material. Depending on the background, part of the marking may remain virtually invisible to the unaided eye.

25 In a second method, the marking is authenticated under ambient light with the help of a passive detecting means such as an optical filter. A preferred such passive detecting means is a left-handed or a right-handed circular polarizing filter, or a juxtaposition of both. This allows determining the rotation
30 sense of the helical pitch of the cholesteric liquid crystal material by determining the polarization state of the light reflected by the said material. Optionally, the polarization filter can be combined with color filters, in order to reduce

the spectral bandwidth to the spectral reflection band of the liquid crystal material, and hence to reduce background contributions. More than one optical filter may be used in conjunction.

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In a third method, the marking is authenticated with the help of circular polarized light from at least one polarized light source. The liquid crystal material reflects differently light of different circular polarization; hence materials of left and of right helical pitch can be distinguished by their respective response to circularly polarized light. The illumination of the marking by the polarized light source, as well as the observation of the reflected light from the marking, may optionally be performed through a color filter. More than one polarized light sources may be used in conjunction.

In a fourth method, the marking is authenticated with the help of an electro-optical authentication device. In a first embodiment, said device comprises at least one photocell, in combination with a circular polarization filter and/or with a circular polarized light source. In another embodiment said device comprises an electro-optic camera, such as a linear CCD sensor array, a 2-dimensional CCD image sensor array, a linear CMOS image sensor array, or a 2-dimensional CMOS image sensor array, in combination with a circular polarization filter and/or with a circular polarized light source.

Optionally, the circular polarization filter or the circular polarized light source in the above embodiments can be combined with color filters, to select a particular spectral domain and to enhance the contrast ratio of the light reflected from the liquid crystal material to the light

reflected from the background.

The circular polarization filters can generally also be replaced by an electro-optic polarization switch. Such device
5 is known in the art, e.g. from DE 102 11 310 B4, and allows to select one or the other circular polarization state by an applied corresponding voltage.

In all cases of cholesteric liquid crystal materials, the
10 marking of the present invention is authenticated by verifying one or more of its characteristic properties, namely the circular polarization state and/or the viewing-angle dependent color of the reflected light from the marking. The polarized light source or the polarized light detection equipment or
15 both may be chosen to operate in the visible, the infrared, or the UV region of the electromagnetic spectrum, or in a combination of these, according to the optical characteristics of the marking.

20 The marking of the present invention can be identified by reading the indicia it represents and by subsequently correlating the information so retrieved from the marking with information stored in a data base. In a particular embodiment, the information represented by the indicia of the marking is
25 encrypted, and said identification comprises the step of decrypting said information. Preferably, the indicia are read by an electro-optic camera, such as a CCD- or a CMOS-image sensor array.

30 In general, the method for identifying an item or article carrying a marking according to the present invention comprises the steps of a) providing an item or article carrying a marking according to the present invention, b)

illuminating the marking on said item or article with at least one quality of light from at least one light source, c) reading the indicia represented by the marking, deriving corresponding information, d) correlating the information
5 retrieved from the indicia of the marking with information stored in a data base, e) obtaining confirmation or denial concerning the item's or articles identity.

The identification of an item or article carrying a marking
10 according to the present invention can be performed with the same reading equipment configuration or assembly which is used for the authentication.

In a first embodiment the said indicia are represented by a 1-
15 dimensional or a 2-dimensional barcode, and the image retrieved by the electro-optic camera in digital form is analyzed using a corresponding algorithm. The information contained in the barcode is retrieved, if necessary, decrypted, and compared with information stored in a data
20 base, hereby identifying the item, and optionally updating the data base with supplementary information, e.g. about the item's history. The camera may be part of a reading device equipped with own communication capabilities, or part of a communication device, such as a mobile phone, the retrieval of
25 the information taking place using the mobile phone's internal resources. The data base may be either located in the communication device (built-in or exchangeable memory), or on an external server reached via a communication network.

30 In a second embodiment the said indicia are represented by an alphanumeric code, and the image retrieved by the electro-optic camera (reading device) in digital form is analyzed using a corresponding optical character recognition (OCR)

algorithm. The information contained in the code is retrieved and compared with information stored in a data base, hereby identifying the item, and optionally updating the data base. As in the first embodiment, the data base may be either
5 located in the reading device (built-in or exchangeable memory), or on an external server reached via a communication network. The alphanumeric code can be printed using a standard font or a special machine identifiable font. Alternatively, the alphanumeric code can be visually read and either sent via
10 a communication system (e.g. Internet or SMS) to a data center for validation or checked against data provided with the item in form of a label, reference mark or another alphanumeric code.

15 The marking of the present invention, made of polymeric liquid crystal material having determined optical characteristics, can be used for the secure tracking and tracing of items, articles or goods with an individualized, counterfeit-resistant code for the secure tracking and tracing of said
20 items, articles or goods.

The application of an individualized code onto a good or item requires a variable information printing process. A preferred variable information printing process in the context of the
25 present invention is chosen from the group of continuous ink-jet printing and drop-on-demand ink-jet printing; these printing processes allow for a rapid, non-contact application of said individualized code onto any kind of surfaces. Said individualized code allows the identification of each single
30 item at a later stage of its life cycle.

In order to prevent the substitution of the original item by a counterfeit carrying a copy of said individualized code, said

individualized code must be counterfeit-resistant. Counterfeit resistance can be provided through a particular security material having particular physical, preferably optical, properties; the said material can be either constitutive or
5 incorporated in the marking. The particular security material can be a polymeric liquid crystal material having determined optical characteristics, or an additive selected from the group of the inorganic luminescent compounds, the organic luminescent compounds, the IR-absorbers, the magnetic
10 materials, the forensic markers, and combinations thereof.

The marking of the present invention can be used on items or articles, such as value documents, banknotes, passports, identity documents, driving licenses, official permissions,
15 access documents, stamps, tax stamps and banderoles (in particular for tobacco products and alcoholic beverages), transportation tickets, event tickets, labels, foils, packaging (in particular for pharmaceutical products), and in general for marking spare parts and consumer goods (in
20 particular to address liability issues).

The marking of the present invention, applied to items, goods, or articles is suitable for use in the secure tracking and tracing of such marked items, goods or articles. Such secure
25 tracking and tracing of an item or article comprises noteworthy the first commutable steps of a) applying a marking according to the invention to the item or article to be traced; and b) storing information related to the marked item or article in a data base; as well as the second commutable
30 steps of c) authenticating the item or article according to the authentication method disclosed herein; and d) identifying the item or article, according to the identification method disclosed herein, using the information previously stored in

the data base. Optionally the data base may hereby be updated with new information elements related to the item or article.

The code applied to the item or good represents digital
5 information, which is stored in a data base, in order to identify the item or good at a later stage. Said code may be encrypted, so as to protect the information it contains upon transmission from and to the data base. Said data base can be part of a data base management system. All kind of encryption
10 algorithms are suitable, e.g. a public-private key of the RSA type.

Said data base may be a local data base, integrated into the authentication device. Alternatively, it may be a remote data
15 base, linked to the authentication device through a wired or wireless connection. A local data base may also be updated regularly from a remote server.

In a further aspect, the present invention provides for the
20 application of the individual marking by a variable-information printing process. Preferred is ink-jet printing, either using the continuous ink-jet, or the drop-on-demand (DOD) ink-jet or valve-jet printing process. Industrial ink-jet printers, commonly used for numbering and coding
25 applications on conditioning lines and printing presses, are particularly suitable. Preferred ink-jet printers are single nozzle continuous ink-jet printers (also called raster or multi level deflected printers) and drop-on-demand ink-jet, in particular valve-jet, printers.

30

To provide for an entirely covert and machine readable marking, nematic liquid crystal materials are used. To provide for an overt or semi-covert and machine readable marking,

cholesteric or chiral-nematic liquid crystal materials are used.

Description of the Drawings

5 For a more complete understanding of the present invention reference is made to the detailed description of the invention and the attached drawings.

Fig.1 schematically depicts a cardboard packaging, e.g. a
10 pharmaceutical packaging, carrying representative markings a), b), c) according to the invention, which are printed with liquid crystal material at different locations on said cardboard packaging:

- 15 a) shows a Data Matrix code on a particularly dark colored background, e.g. a black background;
- b) shows a Data Matrix code on a background of mixed color, e.g. having dark and light colored parts;
- c) shows a Data Matrix code on a white background.

20 Fig.2 shows images captured from an ECC200 data matrix code printed with UV-cured liquid crystal (LC) material on coated cardboard:

- 25 a) LC Data Matrix code retrieved from a black background, under right-circular polarized white light illumination, having a right-circular polarizing filter in front of the CMOS camera.
- b) LC Data Matrix code retrieved from a black/white background, under right-circular polarized white light illumination, having a right-circular polarizing filter
30 in front of the CMOS camera.
- c) LC Data Matrix code retrieved from a black/white background, under right-circular polarized white light illumination, having no filter in front of the CMOS

camera.

- d) LC Data Matrix code retrieved from a black/white background, under unpolarized white light illumination, having no filter in front of the CMOS camera.

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Detailed Description of the Invention

In a first embodiment, the marking of the present invention is made of a liquid crystal precursor composition, which is obtainable by independently applying a liquid crystal precursor composition to a substrate by a variable information printing process, applying heat to both evaporate the solvent contained in the liquid crystal precursor composition and promote the liquid crystal state, and hardening the applied composition in the ordered liquid crystal state. In one exemplary embodiment, the liquid crystal precursor composition is applied to the surface of a substrate. Heat is then applied to both, evaporate the solvent and promote the liquid crystal state. The composition in the liquid crystal state is then polymerized (cured) by irradiation with UV light or with electron beam radiation, as known by the skilled in the art. In an alternative exemplary embodiment, the heat is applied to the whole body of substrate and liquid crystal precursor composition or only to the substrate, if it is able to transmit the applied heat to the liquid crystal precursor composition. In a further alternative embodiment, the liquid crystal precursor composition may be subjected to heat before applying it to the substrate. In an additional alternative embodiment, the step of heating the liquid crystal precursor composition and applying it to a substrate may be performed in a single step.

The liquid crystal material applied in this embodiment is thus a monomeric or oligomeric precursor of a liquid crystal

polymer. Said precursor comprises at least one nematic liquid crystal monomer or oligomer, said monomer or oligomer having polymerizable groups. Suitable nematic liquid crystal monomers or oligomers are from the group of bisacrylates such as

5 2-methyl-1,4-phenylene bis(4-(4-(acryloyloxy)butoxy)benzoate;

1,4-phenylene bis(4-(4-(acryloyloxy)butoxy)benzoate);

10 2-methyl-1,4-phenylene bis(4-(6-(acryloyloxy)hexyloxy)benzoate);

1,4-phenylene bis(4-((4-(acryloyloxy)butoxy)carbonyloxy)benzoate);

15 2-methyl-1,4-phenylene bis(4-((4-(acryloyloxy)butoxy)carbonyloxy)benzoate);

and the combinations thereof.

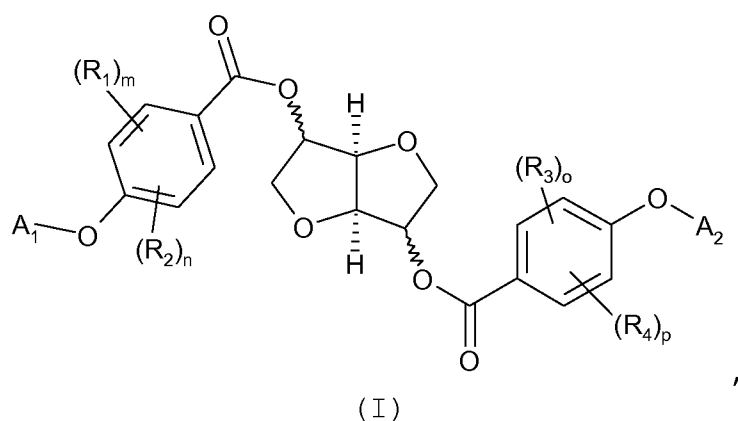
20 The nematic liquid crystal monomer or oligomer may be present in the precursor material in a range of 10% to 100% by weight.

Suitable stabilizers are Florstab UV-1 supplied by Kromachem, and Genorad 16 supplied by Rahn.

25

The photoinitiator may be present in the precursor material in a range of 0.5% to 5% by weight.

30 For obtaining cholesteric (i.e. twisted nematic) phases, said precursor further comprises at least one chiral dopant (chiral inducer). Suitable chiral dopants comprise the derivatives of isomannide and of isosorbide, represented by the general formula (I)



wherein

5

$R_1, R_2, R_3, R_4, R_5, R_6, R_7$ and R_8 denote each independently C_1-C_6 alkyl, C_1-C_6 alkoxy;

A_1 and A_2 denote each independently a group:

10

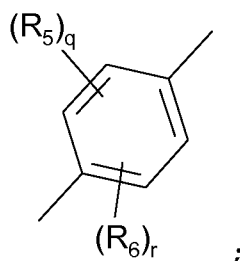
i) $-(CH_2)_y-O]z-C(O)-CH=CH_2$;

ii) $-C(O)-D_1-O-(CH_2)_y-O]z-C(O)-CH=CH_2$;

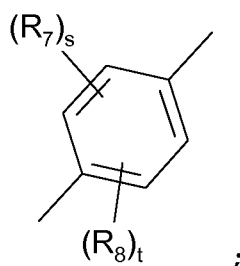
15

iii) $-C(O)-D_2-O-(CH_2)_y-O]z-C(O)-CH=CH_2$;

D_1 denotes a group



20 D_2 denotes a group



25

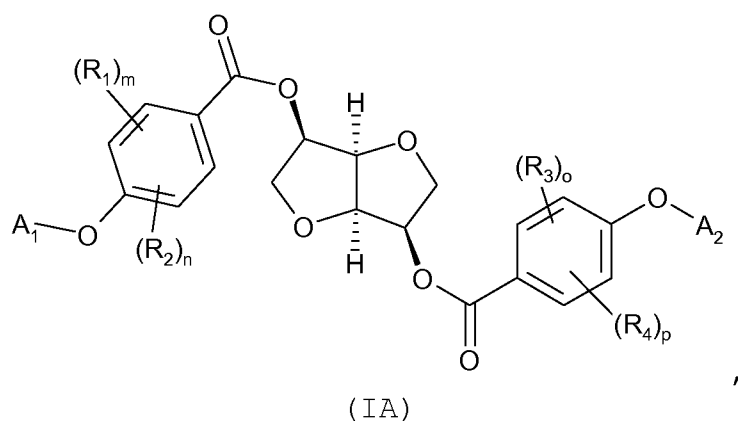
$m, n, o, p, q, r, s,$ and t denote each independently 0, 1, 2;

y denotes 0, 1, 2, 3, 4, 5, 6;

z equal 0 if y equal 0 and z equal 1 if y equal 1 to 6.

In another embodiment chiral dopants comprise the derivatives of isomannide represented by the formula (IA)

5



wherein

10

$R_1, R_2, R_3, R_4, R_5, R_6, R_7$ and R_8 denote each independently C_1 - C_6 alkyl, C_1 - C_6 alkoxy;

A_1 and A_2 denote each independently a group:

15

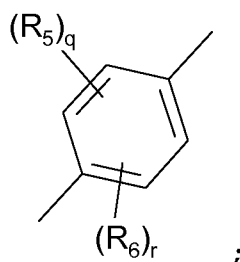
i) $-(CH_2)_y-O]_z-C(O)-CH=CH_2$;

ii) $-C(O)-D_1-O-(CH_2)_y-O]_z-C(O)-CH=CH_2$;

20

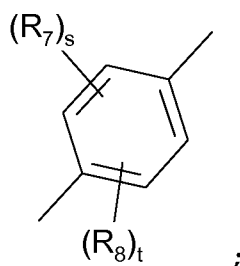
iii) $-C(O)-D_2-O-(CH_2)_y-O]_z-C(O)-CH=CH_2$;

D_1 denotes a group



25

D_2 denotes a group



m, n, o, p, q, r, s, and t denote each independently 0, 1, 2;
 5 y denotes 0, 1, 2, 3, 4, 5, 6;

z equal 0 if y equal 0 and z equal 1 if y equal 1 to 6.

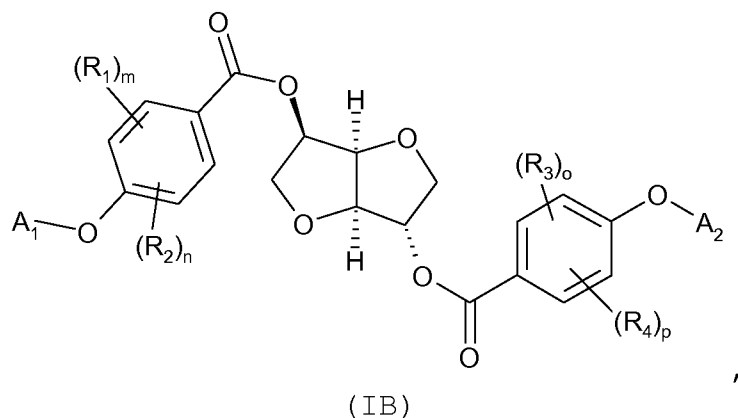
10 In a preferred embodiment, in formula (IA), R_1 , R_2 , R_3 , R_4 , R_5 , R_6 , R_7 and R_8 denote each independently C_1 - C_6 alkyl. In an alternative embodiment, in formula (IA), R_1 , R_2 , R_3 , R_4 , R_5 , R_6 , R_7 and R_8 denote each independently C_1 - C_6 alkoxy.

15 In a further preferred embodiment, in formula (IA), A_1 and A_2 denote each independently i) $-(CH_2)_y-O]z-C(O)-CH=CH_2$; R_1 , R_2 , R_3 and R_4 denote each independently C_1 - C_6 alkyl; and m, n, o, and p denote each independently 0, 1, 2. In an alternative embodiment, in formula (IA), A_1 and A_2 denote each

20 independently ii) $-(CH_2)_y-O]z-C(O)-CH=CH_2$; R_1 , R_2 , R_3 and R_4 denote each independently C_1 - C_6 alkoxy; and m, n, o, and p denote each independently 0, 1, 2.

In other preferred embodiment of formula (IA), A_1 and A_2 denote
 25 each independently ii) $-C(O)-D_1-O-[(CH_2)_y-O]z-C(O)-CH=CH_2$ and/or iii) $-C(O)-D_2-O-[(CH_2)_y-O]z-C(O)-CH=CH_2$; and R_1 , R_2 , R_3 , R_4 , R_5 , R_6 , R_7 and R_8 denote each independently C_1 - C_6 alkyl. In an alternative embodiment, in formula (IA), A_1 and A_2 denote each independently ii) $-C(O)-D_1-O-[(CH_2)_y-O]z-C(O)-CH=CH_2$
 30 and/or iii) $-C(O)-D_2-O-[(CH_2)_y-O]z-C(O)-CH=CH_2$; and R_1 , R_2 , R_3 , R_4 , R_5 , R_6 , R_7 and R_8 denote each independently C_1 - C_6 alkoxy.

In another embodiment chiral dopants comprise the derivatives of isosorbide represented by the formula (IB)



wherein

10 $R_1, R_2, R_3, R_4, R_5, R_6, R_7$ and R_8 denote each independently C_1 - C_6 alkyl, C_1 - C_6 alkoxy;

A_1 and A_2 denote each independently a group:

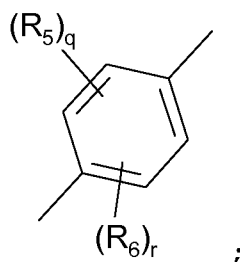
15 i) $-(CH_2)_y-O-z-C(O)-CH=CH_2$;

ii) $-C(O)-D_1-O-(CH_2)_y-O-z-C(O)-CH=CH_2$;

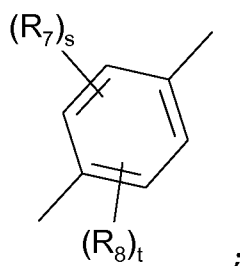
iii) $-C(O)-D_2-O-(CH_2)_y-O-z-C(O)-CH=CH_2$;

20

D_1 denotes a group



D_2 denotes a group



25

m, n, o, p, q, r, s, and t denote each independently 0, 1, 2;

5 y denotes 0, 1, 2, 3, 4, 5, 6;

z equal 0 if y equal 0 and z equal 1 if y equal 1 to 6.

In a preferred embodiment, in formula (IB), R₁, R₂, R₃, R₄, R₅,
10 R₆, R₇ and R₈ denote each independently C₁-C₆ alkyl. In an
alternative embodiment, in formula (IB), R₁, R₂, R₃, R₄, R₅, R₆,
R₇ and R₈ denote each independently C₁-C₆ alkoxy.

In a further preferred embodiment, in formula (IB), A₁ and A₂
15 denote each independently i) -[(CH₂)y-O]z-C(O)-CH=CH₂; R₁, R₂,
R₃ and R₄ denote each independently C₁-C₆ alkyl; and m, n, o,
and p denote each independently 0, 1, 2. In an alternative
embodiment, in formula (IB), A₁ and A₂ denote each
independently i) -[(CH₂)y-O]z-C(O)-CH=CH₂; R₁, R₂, R₃ and R₄
20 denote each independently C₁-C₆ alkoxy; and m, n, o, and p
denote each independently 0, 1, 2.

In other preferred embodiment, in formula (IB), A₁ and A₂
denote each independently ii) -C(O)-D₁-O-[(CH₂)y-O]z-C(O)-
25 CH=CH₂ and/or iii) -C(O)-D₂-O-[(CH₂)y-O]z-C(O)-CH=CH₂; and R₁,
R₂, R₃, R₄, R₅, R₆, R₇ and R₈ denote each independently C₁-C₆
alkyl. In an alternative embodiment, in formula (IB), A₁ and A₂
denote each independently ii) -C(O)-D₁-O-[(CH₂)y-O]z-C(O)-
CH=CH₂ and/or iii) -C(O)-D₂-O-[(CH₂)y-O]z-C(O)-CH=CH₂; and R₁,
30 R₂, R₃, R₄, R₅, R₆, R₇ and R₈ denote each independently C₁-C₆
alkoxy.

In a preferred embodiment, in the formulae (I), (IA) and/or
(IB), the alkyl or alkoxy group of R₁, R₂, R₃, R₄, R₅, R₆, R₇ and
35 R₈ may comprise 4 or 6 carbon atoms.

Alkyl groups comprising 4 carbon atoms may be selected from the group comprising butyl or isopropyl. Alkyl groups comprising 6 carbon atoms may be selected from the group comprising hexyl, 2-methylpentyl, 3-methylpentyl, 2,2-
 5 dimethylpentyl or 2,3-dimethylpentyl.

Alkoxy groups comprising 4 carbon atoms may be selected from the group comprising but-1-oxy, but-2-oxy, isopropoxy or *tert*-butoxy. Alkoxy groups comprising 6 carbon atoms may be
 10 selected from the group comprising hex-1-oxy, hex-2-oxy, hexan-3-ol, 2-methylpentan-1-ol, 2-methylpentan-2-ol, 2-methylhydroxypentane, 2-methylpent-3-oxy, 2-methylpent-4-oxy, 4-methylpent-1-oxy, 3-methylpent-1-oxy, 3-methylpent-2-oxy, 3-methylpent-3-oxy, 3-methylhydroxypentane, 2,2-dimethylpent-1-
 15 oxy, 2,2-dimethylpent-3-oxy, 2,2-dimethylpent-4-oxy, 4,4-dimethylpent-1-oxy, 2-methyl-2-methylhydroxypentane, 2,3-dimethylpent-1-oxy, 2,3-dimethylpent-2-oxy, 2,3-dimethylpent-3-oxy, 2,3-dimethylpent-4-oxy, 3,4-dimethylpent-1-oxy, 2-methylhydroxy-3-methylpentane or 2-methyl-3-
 20 methylhydroxypentane.

Chiral dopant according to the invention include in particular those selected from the following group:

25 (3R, 3aR, 6R, 6aR)-hexahydrofuro[3,2-b]furan-3,6-diyl bis(4-(4-(acryloyloxy)benzoyloxy)benzoate);
 (3R, 3aR, 6R, 6aR)-hexahydrofuro[3,2-b]furan-3,6-diyl bis(4-(4-(acryloyloxy)butoxy)benzoate);
 (3R, 3aR, 6R, 6aR)-hexahydrofuro[3,2-b]furan-3,6-diyl bis(4-
 30 (acryloyloxy)-2-methylbenzoate);
 (3R, 3aR, 6S, 6aR)-hexahydrofuro[3,2-b]furan-3,6-diyl bis(4-(4-(acryloyloxy)benzoyloxy)-3-methoxybenzoate);

(3R, 3aR, 6R, 6aR)-hexahydrofuro[3,2-b]furan-3,6-diyl bis(4-(4-(acryloyloxy)-3-methoxybenzoyloxy)benzoate);
 (3R, 3aR, 6R, 6aR)-6-(4-(4-(acryloyloxy)-3-methoxybenzoyloxy)-3-methoxybenzoyloxy)hexahydro furo[3,2-b]furan-3-yl 4-(4-(acryloyloxy)benzoyloxy)-3-methoxybenzoate;
 5 (3R, 3aR, 6R, 6aR)-hexahydrofuro[3,2-b]furan-3,6-diyl bis(4-(4-(acryloyloxy)-3-methoxybenzoyloxy)-3-methoxybenzoate); and
 (3R, 3aR, 6R, 6aR)-hexahydrofuro[3,2-b]furan-3,6-diyl bis(4-(4-(acryloyloxy)benzoyloxy)-3-methoxybenzoate).

10

The chiral dopant may be present in the precursor material in a range of 0.1% to 25% by weight.

A variable information printing process is used to apply the
 15 liquid crystal precursor material to the substrate. The term "variable information printing" encompasses also variable data printing. This form of printing process is a printing process in which elements such as text, graphics or images may be changed from one printed piece to the next, allowing the
 20 "mass-customization" of items as opposed to the "mass-production" of a single item, e.g. using offset lithography, without delaying or stopping the press being necessary. A basic design is developed which comprises various sections which may be altered using a database of information that
 25 fills in the changeable fields according to the demand and intention of the user. Depending on the number of changeable fields, the final product is more or less sophisticated, e.g. like a marking according to the present invention. The elements and/or sections to be changed on each individual item
 30 can be determined in advance and controlled in each moment.

The marking is preferably applied by ink-jet printing, either of the continuous ink-jet or of the drop-on-demand ink-jet

type, preferably by single nozzle/ raster. For application by ink-jet printing, the composition must further contain a solvent, in order to adjust its viscosity to the low values required by the said printing processes. Typical viscosity
5 values for ink-jet printing inks are in the range of 4 to 30 mPa.s at 25°C. Solvents, which can be used are chosen from the group of the low-viscosity, slightly polar and aprotic organic solvents, such as methyl-ethyl-ketone (MEK), acetone, ethylacetate, ethyl 3-ethoxypropionate or toluene. Chlorinated
10 solvents like dichloromethane, trichloromethane or trichloroethylene are technically suitable, but not desirable in printing inks because of their toxicity.

The solvent is comprised in the ink-jet precursor material in
15 a range of 10% to 95%, typically 45% to 85% by weight.

In the case of continuous ink-jet printing, the precursor material also comprises a dissolved conducting agent, typically a salt, such as lithium nitrate, lithium
20 perchlorate, tetrabutylammonium chloride or tetrabutylammonium tetrafluoroborate.

The salt is present in a concentration range of 0.1 to 5% by weight.

25

The precursor material preferably may further comprise security materials, which are present in low to moderate concentration, in order to increase the resistance of the marking towards counterfeiting. These security materials are
30 selected from the group consisting of the inorganic luminescent compounds, the organic luminescent compounds, the IR-absorbers, the magnetic materials, the forensic markers, and combinations thereof. Concentration ranges are 0.01% to 5%

for luminescent compounds, 0.1% to 10% for IR-absorbers or magnetic materials, and 0.001% to 1% for forensic marker materials.

- 5 The preferred cholesteric liquid crystal precursor material for carrying out the present invention using ink-jet printing equipment comprises a mixture of at least one nematic compound, at least one chiral inducer compound according to formula (I), (IA) or (IB), an organic solvent, and a
10 photoinitiator.

Said nematic compound is preferably of the acrylic- or bis-acrylic type as disclosed in EP-A-0 216 712 and EP-B-0 847 432, US-B-6,589,445, which are herein included by reference.

- 15 The preferred amount of the nematic compound present in the cholesteric liquid crystal precursor mixture is from about 10 wt% to about 60 wt%, more preferably from about 10 wt% to about 45 wt%.
- 20 The amount of the chiral inducer present in the cholesteric liquid crystal precursor mixture ranges from about 0.1 wt% to about 25 wt%, preferably from about 0.5 wt% to about 15 wt%.

- The liquid crystal precursor material for producing a marking
25 according to the present invention may further comprise dyes, pigments, coloring agents, diluents, conducting salts, surface-active compounds, surface adhesion promoters, wetting agents, defoamers, and dispersing agents.

- 30 The marking of the present invention is preferably applied in the form of indicia representing a unique 1-dimensional, a stacked 1-dimensional, or a 2-dimensional barcode or matrix code. The symbology is preferably chosen among those used in

the retail industry for the marking of commercial goods. These symbologies are internationally recognized standards, and the corresponding reading and decoding algorithms are known and implemented in commercially available devices.

5

Suitable 1-dimensional and stacked 1-dimensional barcode symbologies are known to the skilled person and available under symbology names such as Plessey, U.P.C., Codabar, Code 25 - Non-interleaved 2 of 5, Code 25 - Interleaved 2 of 5,
 10 Code 39, Code 93, Code 128, Code 128A, Code 128B, Code 128C, Code 11, CPC Binary, DUN 14, EAN 2, EAN 5, EAN 8, EAN 13, GS1-128 (formerly known as UCC/EAN-128), EAN 128, UCC 128, GS1 DataBar formerly Reduced Space Symbology (RSS), ITF-14, Pharmacode, PLANET, POSTNET, OneCode, MSI, PostBar, RM4SCC /
 15 KIX, or Telepen.

Suitable 2-dimensional barcode symbologies are known to the skilled person and available under symbology names such as 3-DI, ArrayTag, Aztec Code, Small Aztec Code, bCODE, Bullseye,
 20 Codablock, Code 1, Code, 16K, Code 49, Color code, CP Code, DataGlyphs, Datamatrix, Datastrip Code, Dot Code A, EZcode, High Capacity Color Barcode, HueCode, INTACTA.CODE, InterCode, MaxiCode, mCode, MiniCode, PDF417, Micro PDF417, PDMark, PaperDisk, Optar, QR Code, Semacode, SmartCode, Snowflake
 25 Code, ShotCode, SuperCode, Trillcode, UltraCode, VeriCode, VSCode, WaterCode, and ECC200. This latter has a built-in error correction code and is defined in international standard ISO/CEI 16022:2006.

30 Suitable font types for optical character recognition (OCR) are known to the skilled person.

Fig.1 schematically shows a product packaging having a

cholesteric liquid crystal marking of the present invention. The marking is present in the form of a ECC200 data matrix code on the surface of said packaging. Data Matrix ECC200 is a public domain symbology. The marking can be applied to any
5 desired position on the packaging. Thus it can be present wholly on a first background color (a), or partially, overlapping with a first background color and a second design color motive present on the packaging (b), or wholly be present on a white or colorless region of the packaging (c).

10

The reading device for reading the marking of the present invention can be constructed on the basis of commercially available barcode readers, in particular on the basis of hand-held CCD/CMOS-camera reading equipment and reading stations
15 used in the retail industry. In case of an appropriate matching of the marking with the available (narrow-band) illumination, said reading equipment may be directly enabled to read the liquid crystal codes.

20 In other cases, the reading device can be further adapted (enabled) so as to read the response of the specific security elements implemented in the marking. Correspondingly adapted flat-bed scanners can also be used. CCD-camera based barcode readers are known to the skilled person and are produced by
25 several industrial companies, such as AccuSort, Cognex, DVT, Microscan, Omron, Sick, RVSI, Keyence, etc.

Said adaptation of the reading device may comprise the implementation of one or several optical filters chosen from
30 the group of linear polarizing filters, right-circular polarizing filters, left-circular polarizing filters, electro-optic polarization filters, wave-plates, and spectrally selective color filters of any type, and combinations thereof.

In a particular embodiment at least two different optical filters are used. Said adaptation may further comprise the implementation of one or several particular light sources chosen from the group of spectrally selective (i.e. colored) light sources, linear polarized light sources, left- and right-circular polarized light sources, and combinations thereof.

The light sources, however, can be chosen from ambient light, incandescent light, laser diodes, light emitting diodes, and all type of light sources having color filters. Said light sources may have an emission spectrum in the spectral domain of the visible light (400-700nm wavelength), the near optical infrared (700-1100nm wavelength), the far optical infrared (1100-2500nm wavelength), or the UV (200-400nm wavelength) region of the electromagnetic spectrum.

Said reading device is thus not only enabled to read the marking, but also to authenticate it as being made of the correct security material, i.e. comprising the required security elements. Said reading device delivers a digital information representative of the code which has been read, and pointing towards an entry in a data base corresponding to the item carrying the said marking and code.

25

Said digital information may be compared with information stored in the reading device or may be exchanged between the reading device and an external data base; the exchange can take place in encrypted form, using e.g. a public/private encoding of the RSA type. Said exchange of information can take place by all kind of transmission means, e.g. wire-bound transmission, wireless radio link, infrared-link, etc.

30

- Said coating composition may preferably comprise further security materials, which are present in low to moderate concentration, in order to increase its resistance towards counterfeiting. These security materials are selected from the group consisting of the inorganic luminescent compounds, the organic luminescent compounds, the IR-absorbers, the magnetic materials, the forensic markers, and combinations thereof. Typical concentration ranges are 0.01% to 5% for luminescent compounds, 0.1% to 10% for IR-absorbers or magnetic materials, and 0.001% to 1% for forensic marker materials.
- To accommodate particular conditions, the coating composition for producing a marking according to the present invention may further comprise dyes, pigments, coloring agents, diluents, conducting salts, surface-active compounds, surface adhesion promoters, wetting agents, defoamers, and dispersing agents, as known in the art.

The authentication and identification of the liquid crystal marking according to the present invention requires a light source and must be done in one of the following ways:

- i) by illuminating the marking with circular or linear polarized light and detecting the marking's reflection;
- ii) by illuminating the marking with unpolarized (e.g. ambient) light and detecting the marking's reflection through a circular or linear polarizing filter,
- iii) by a combination of circular or linear polarized illumination and detection through a circular or linear polarizing filter.

The illumination of a marked item or article is thus performed by a light source chosen from unpolarized light sources, linear polarized light sources, left circular polarized light sources, and right circular polarized light sources.

5

In all cases, detection may be performed by eye or with the help of electro-optic detection equipment, such as a photocell, or a CCD or CMOS camera. The light sources and the detection may be made or chosen spectrally selective through the use of particular light emitters and/or color filters. The detection is preferably carried out in the visible region (400-700nm wavelength) of the electromagnetic spectrum.

In a particular embodiment the illumination of the marking for authenticating an item or article, is performed using at least two different light sources selected from non-polarized (randomly polarized) light sources, linear polarized light sources, left circular polarized light sources, and right circular polarized light sources.

20

Fig.2 shows images taken from ECC200 Data matrix codes printed with liquid crystal material on coated cardboard. These images clearly illustrate the advantage of using the polarizing properties of the liquid crystal material marking for the reading of the printed code on a clear or structured background. Most advantageous is a combination of polarized light for illumination and the use of a polarizing filter in front of the camera. All images were taken with the same light source and with the same camera settings, all in black and white mode, and with or without polarizing filters before the light source and/or the camera. The images were digitally treated for maximum contrast and optimum brightness.

30

In a preferred option, the liquid crystal marking of the present invention is rendered visible under unpolarized (preferably ambient) light by a passive detecting means such as a linear or a circular polarizing filter. The marking can, however, also be identified and authenticated outside the visible spectrum (400-700nm wavelength), e.g. in the infrared region (700 to 2500nm wavelength), preferably in the near optical infrared (700-1100nm wavelength), in the far optical infrared (1100-2500nm wavelength) or in the UV (200-400nm wavelength) region of the electromagnetic spectrum, given that the marking has a reflection band in these regions.

The cholesteric liquid crystal polymer is, by its nature, a spectrally selective reflector whose reflection band can be tuned across part of the electromagnetic spectrum by an appropriate choice of its helical pitch. Said pitch noteworthy depends on the ratio of nematic precursor material to chiral inducer compound in the liquid crystal precursor, and on the temperature of polymerization. After polymerization, the helical pitch, and hence the reflection color of the material, remains fixed.

As known to the skilled person, low amounts of chiral inducer result in a low helical twisting and hence in a large helical pitch. Therefore, low amounts of the chiral inducer generate a reflection band of the resulting polymer at the long wavelength end of the spectrum, typically in the infrared or red region, whereas higher amounts of inducer generate a reflection band of the resulting polymer at the short wavelength end of the spectrum, typically in the blue or UV region.

Attention must also be paid to the handedness of the chiral

inducer, i.e. whether a determined inducer results in a left or in a right helical pitch, resulting in respective opposite circular polarization of the reflected light. Isomannide derivatives are known to induce the reflection of left
 5 circular polarized light, whereas isosorbide derivatives are known to induce the reflection of right circular polarized light.

Hereafter is given a typical example of a cholesteric liquid
 10 crystal polymer precursor composition, which can be applied by the continuous ink-jet printing process:

Example 1

Composition	Weight %
Acetone	52.25
2-methyl-1,4-phenylene bis(4-(4-(acryloyloxy)butoxy)benzoate)	38.8
(3R,3aR,6R,6aR)-hexahydrofuro[3,2-b]furan-3,6-diyl bis(4-(4-(acryloyloxy)benzoyloxy)-3-methoxybenzoate)	7.5
Irgacure 907	1.0
LiClO ₄	0.45

15 Example 2

Composition	Weight %
Acetone	52.25
2-methyl-1,4-phenylene bis(4-(4-(acryloyloxy)butoxy)benzoate)	38.8
(3R,3aR,6R,6aR)-6-(4-(4-(acryloyloxy)-3-methoxybenzoyloxy)-3-methoxybenzoyloxy)hexahydrofuro[3,2-b]furan-3-yl 4-(4-(acryloyloxy)benzoyloxy)-3-methoxybenzoate	7.5

Irgacure 907	1.0
LiClO ₄	0.45

Example 3

Composition	Weight %
Acetone	55.29
2-methyl-1,4-phenylene bis(4-(4-(acryloyloxy)butoxy)benzoate)	41.07
(3R,3aR,6S,6aR)-hexahydrofuro[3,2-b]furan-3,6-diyl bis(4-(4-(acryloyloxy)benzoyloxy)-3-methoxybenzoate)	2.11
Irgacure 907	1.05
LiClO ₄	0.48

Example 4

Composition	Weight %
Acetone	52.25
2-methyl-1,4-phenylene bis(4-(4-(acryloyloxy)butoxy)benzoate)	38.8
(3R,3aR,6R,6aR)-hexahydrofuro[3,2-b]furan-3,6-diyl bis(4-(4-(acryloyloxy)-3-methoxybenzoyloxy)-3-methoxybenzoate)	7.5
Irgacure 907	1.0
LiClO ₄	0.45

5

Example 5

Composition	Weight %
Acetone	52.25
2-methyl-1,4-phenylene bis(4-(4-	38.8

(acryloyloxy)butoxy)benzoate)	
(3R,3aR,6R,6aR)-hexahydrofuro[3,2-b]furan-3,6-diyl bis(4-(4-(acryloyloxy)-3-methoxybenzoyloxy)benzoate)	7.5
Irgacure 907	1.0
LiClO4	0.45

Example 6

Composition	Weight %
Methyl ethyl ketone (MEK)	52.25
2-methyl-1,4-phenylene bis(4-(4-(acryloyloxy)butoxy)benzoate)	38.8
(3R,3aR,6R,6aR)-hexahydrofuro[3,2-b]furan-3,6-diyl bis(4-(4-(acryloyloxy)benzoyloxy)benzoate)	7.5
Irgacure 907	1.0
LiClO4	0.45

Example 7

Composition	Weight %
Acetone	48.6
2-methyl-1,4-phenylene bis(4-(4-(acryloyloxy)butoxy)benzoate)	36.1
(3R,3aR,6R,6aR)-hexahydrofuro[3,2-b]furan-3,6-diyl bis(4-(4-(acryloyloxy)butoxy)benzoate)	13.95
Irgacure 907	0.93
LiClO4	0.42

5

Example 8

Composition	Weight %
Acetone	49.25

2-methyl-1,4-phenylene bis(4-(4-(acryloyloxy)butoxy)benzoate)	36.6
(3R,3aR,6R,6aR)-hexahydrofuro[3,2-b]furan-3,6-diyl bis(4-(acryloyloxy)-2-methylbenzoate)	12.74
Irgacure 907	0.94
LiClO4	0.47

Based on the indications and exemplary embodiments given
hereinbefore, the skilled person is enabled to derive further
5 embodiments of the present invention.

Claims:

1. Marking for an item or article, said marking comprising
polymeric liquid crystal material having determined optical
5 characteristics which allow for its authentication and
reading by a machine, as well as its authentication by the
human eye, the marking being characterized in that it is
obtainable by independently applying a liquid crystal
precursor composition to a substrate by a variable
10 information printing process, applying heat to both
evaporate the solvent contained in the liquid crystal
precursor composition and promote the liquid crystal state,
and hardening the applied composition in the ordered liquid
crystal state, said marking having the form of indicia
15 representing a unique code, allowing for its
identification.
2. Marking according to claim 1, wherein the precursor
composition comprises UV-cure-able reactive monomers or
20 oligomers, and the hardening of the applied composition
takes place by UV-curing.
3. Marking according to claims 1 to 2, characterized in that
25 at least part of the marking is invisible to the unaided
human eye.
4. Marking according to one of the claims 1 to 3, wherein said
polymeric liquid crystal material is a cholesteric liquid
30 crystal material, exhibiting color and an angle-dependent
change of color.

5. Marking according to claim 4, wherein the cholesteric liquid crystal material has a reflection band in the UV spectrum corresponding to the 200 to 400nm wavelength range.

5

6. Marking according to claim 4, wherein the cholesteric liquid crystal material has a reflection band in the visible spectrum corresponding to the 400 to 700nm wavelength range.

10

7. Marking according to claim 4, wherein the cholesteric liquid crystal material has a reflection band in the infrared spectrum corresponding to the 700 to 2500nm wavelength range, preferably in the infrared spectrum corresponding to the 700 to 1100nm wavelength range.

15

8. Marking according to one of the claims 5 to 7, wherein the cholesteric liquid crystal material has a second reflection band in the 200 to 2500nm wavelength range.

20

9. Marking according to one of the claims 1 to 3, wherein said polymeric liquid crystal material is a nematic liquid crystal material, exhibiting optical birefringence.

25

10. Marking according to one of the claims 1 to 9, wherein said polymeric liquid crystal material comprises further security materials, selected from the group consisting of the inorganic luminescent compounds, the organic luminescent compounds, the IR-absorbers, the magnetic materials, and the forensic markers, and the combinations thereof.

30

11. Marking according to one of the claims 1 to 10, wherein

said substrate is selected from the group of reflecting substrates, colored substrates, and transparent substrates.

12. Marking according to one of the claims 1 to 10, wherein
5 said substrate is a patterned substrate, comprising at least two different surface areas, each selected from the group of white surface areas, black surface areas, colored surface areas, reflecting surface areas, transparent surface areas and combinations thereof.

10

13. Marking according to one of the claims 1 to 10, wherein said substrate carries indicia.

14. Marking according to one of the claims 1 to 10, wherein
15 said substrate carries at least one security element, selected from the group consisting of the inorganic luminescent compounds, the organic luminescent compounds, the IR-absorbers, the magnetic materials, the forensic markers and combinations thereof.

20

15. Marking according to claim 14, wherein said security element is present in the form of indicia.

16. Marking according to one of the claims 1 to 15, wherein
25 said substrate is selected from the group consisting of the woven substrates, the non-woven substrates, the coated substrates, the papers, the cardboards, the wooden substrates, the glass substrates, the ceramic substrates, the metal substrates, the plastic substrates, the textiles,
30 and the leathers.

17. Marking according to one of the claims 1 to 16, wherein said marking is obtainable by a process selected from the

group of continuous ink-jet printing, drop-on-demand ink-jet printing, and laser printing.

18. Marking according to one of the claims 1 to 17, wherein
5 said indicia representing a unique code are chosen from the group of: 1-dimensional barcodes, stacked 1-dimensional barcodes, and 2-dimensional barcodes.

10 19. Marking according to claim 18, wherein said 1-dimensional barcode is selected from the group of Plessey, U.P.C., Codabar, Code 25 - Non-interleaved 2 of 5, Code 25 - Interleaved 2 of 5, Code 39, Code 93, Code 128, Code 128A, Code 128B, Code 128C, Code 11, CPC Binary, DUN 14, EAN 2,
15 EAN 5, EAN 8, EAN 13, GS1-128 (formerly known as UCC/EAN-128), EAN 128, UCC 128, GS1 DataBar formerly Reduced Space Symbology (RSS), ITF-14, Pharmacode, PLANET, POSTNET, OneCode, MSI, PostBar, RM4SCC / KIX, or Telepen.

20 20. Marking according to claim 18, wherein said 2-dimensional barcode is selected from the group of 3-DI, ArrayTag, Aztec Code, Small Aztec Code, bCODE, Bullseye, Codablock, Code 1, Code, 16K, Code 49, Color code, CP Code, DataGlyphs, Datamatrix, Datastrip Code, Dot Code A, EZcode, High
25 Capacity Color Barcode, HueCode, INTACTA.CODE, InterCode, MaxiCode, mCode, MiniCode, PDF417, Micro PDF417, PDMark, PaperDisk, Optar, QR Code, Semacode, SmartCode, Snowflake Code, ShotCode, SuperCode, Trillcode, UltraCode, VeriCode, VSCode, WaterCode, and ECC200.

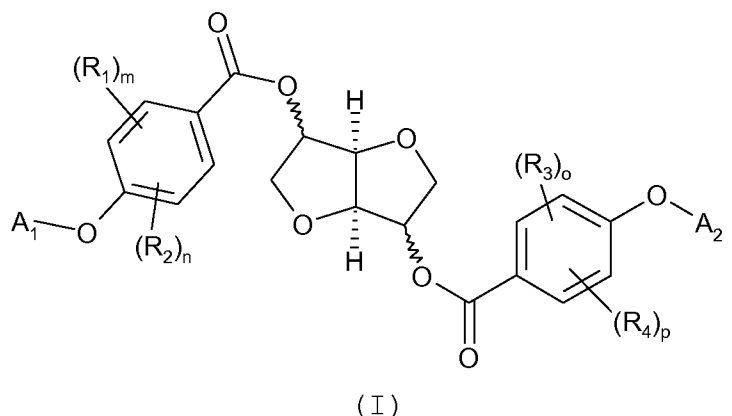
30

21. Marking according to one of the claims 1 to 20, wherein the polymeric liquid crystal material is present in the form of pigment flakes comprised in a suitable binder.

22. Marking according to claim 21, wherein the binder is chosen from the group consisting of the vinylic resins, the acrylic resins, the styrene-maleic anhydride copolymer resins, the polyacetal resins, the polyester resins, the fatty acid modified polyester resins and the mixtures thereof.

23. Marking according to claim 21, wherein the binder is chosen from the group consisting of the UV-cure-able monomers and oligomers of acrylates, vinyl ethers, epoxides and combinations thereof.

24. Marking according to any one of the preceding claims, wherein said polymeric liquid crystal composition is obtainable in the presence of a chiral dopant according to formula (I)



wherein

R_1 , R_2 , R_3 , R_4 , R_5 , R_6 , R_7 and R_8 denote each independently C_1 - C_6 alkyl, C_1 - C_6 alkoxy;

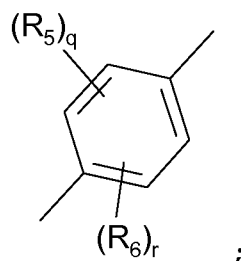
A_1 and A_2 denote each independently a group:

i) $-(CH_2)_y-O]_z-C(O)-CH=CH_2$;

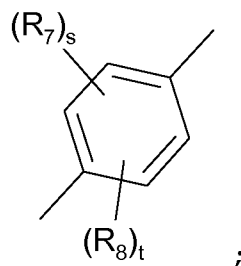
ii) $-\text{C}(\text{O})-\text{D}_1-\text{O}-[(\text{CH}_2)_y-\text{O}]_z-\text{C}(\text{O})-\text{CH}=\text{CH}_2$;

iii) $-\text{C}(\text{O})-\text{D}_2-\text{O}-[(\text{CH}_2)_y-\text{O}]_z-\text{C}(\text{O})-\text{CH}=\text{CH}_2$;

5 D_1 denotes a group



D_2 denotes a group



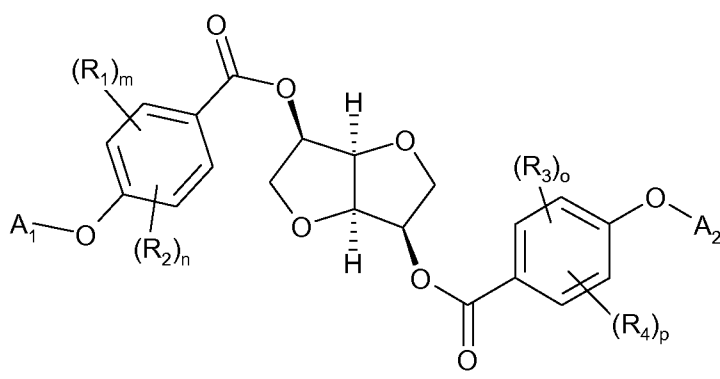
10

$m, n, o, p, q, r, s,$ and t denote each independently 0, 1, 2;

15 y denotes 0, 1, 2, 3, 4, 5, 6;

z equal 0 if y equal 0 and z equal 1 if y equal 1 to 6.

20 25. Marking according to claim 24, wherein said polymeric liquid crystal composition is obtainable in the presence of a chiral dopant according to formula (IA)



(IA)

wherein

5 $R_1, R_2, R_3, R_4, R_5, R_6, R_7$ and R_8 denote each independently C_1 - C_6 alkyl, C_1 - C_6 alkoxy;

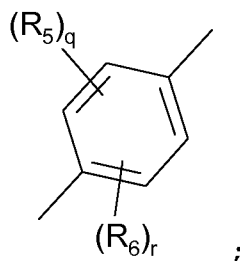
A_1 and A_2 denote each independently a group:

10 i) $-(CH_2)_y-O)_z-C(O)-CH=CH_2$;

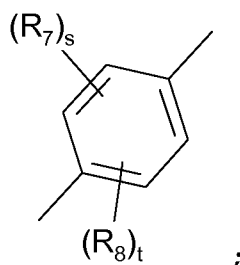
ii) $-C(O)-D_1-O-(CH_2)_y-O)_z-C(O)-CH=CH_2$;

15 iii) $-C(O)-D_2-O-(CH_2)_y-O)_z-C(O)-CH=CH_2$;

D_1 denotes a group



D_2 denotes a group

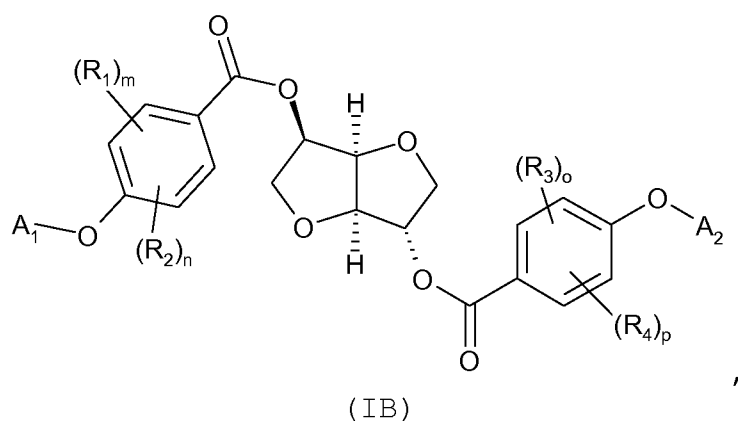


$m, n, o, p, q, r, s,$ and t denote each independently 0, 1, 2;

25 y denotes 0,1,2,3,4,5,6;

z equal 0 if y equal 0 and z equal 1 if y equal 1 to 6.

26. Marking according to claim 24, wherein said polymeric liquid
30 crystal composition is obtainable in the presence of a
chiral dopant according to formula (IB)



wherein

5

R_1 , R_2 , R_3 , R_4 , R_5 , R_6 , R_7 and R_8 denote each independently C_1 - C_6 alkyl, C_1 - C_6 alkoxy;

A_1 and A_2 denote each independently a group:

10

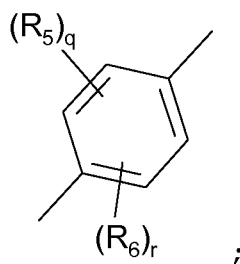
i) $-(CH_2)_y-O]z-C(O)-CH=CH_2$;

ii) $-C(O)-D_1-O-(CH_2)_y-O]z-C(O)-CH=CH_2$;

15

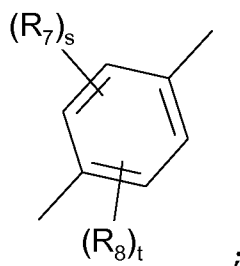
iii) $-C(O)-D_2-O-(CH_2)_y-O]z-C(O)-CH=CH_2$;

D_1 denotes a group



20

D_2 denotes a group



25

m , n , o , p , q , r , s , and t denote each independently 0, 1, 2;

y denotes 0,1,2,3,4,5,6;

z equal 0 if y equal 0 and z equal 1 if y equal 1 to 6.

5 27. Marking according to claim 25 and/or 26, wherein R_1 , R_2 , R_3 , R_4 , R_5 , R_6 , R_7 and R_8 denote each independently C_1 - C_6 alkyl.

28. Marking according to claim 25 and/or 26, wherein R_1 , R_2 , R_3 , R_4 , R_5 , R_6 , R_7 and R_8 denote each independently C_1 - C_6 alkoxy.

10

29. Marking according to claim 25 and/or 26, wherein A_1 and A_2 denote each independently i) $-[(CH_2)_y-O]_z-C(O)-CH=CH_2$; R_1 , R_2 , R_3 and R_4 denote each independently C_1 - C_6 alkyl or C_1 - C_6 alkoxy; and m, n, o, and p denote each independently 0, 1,
15 2.

30. Marking according to claim 25 and/or 26, wherein A_1 and A_2 denote each independently ii) $-C(O)-D_1-O-[(CH_2)_y-O]_z-C(O)-CH=CH_2$ and/or iii) $-C(O)-D_2-O-[(CH_2)_y-O]_z-C(O)-CH=CH_2$; and
20 R_1 , R_2 , R_3 , R_4 , R_5 , R_6 , R_7 and R_8 denote each independently C_1 - C_6 alkyl or C_1 - C_6 alkoxy.

31. Marking according to the claims 25 and/or 26, wherein the alkyl or alkoxy group of R_1 , R_2 , R_3 , R_4 , R_5 , R_6 , R_7 and R_8 may
25 comprise 4 or 6 carbon atoms.

32. Item or article carrying at least one marking according to one of the claims 1 to 31.

30 33. Item or article according to claim 32, wherein said item or article is chosen from the group of value documents, banknotes, passports, identity documents, driving licenses, official permissions, access documents, stamps, tax stamps and banderoles, transportation tickets, event tickets,

labels, foils, packaging, spare parts, and consumer goods.

34. Use of a marking according to one of the claims 1 to 31 for tracking or tracing an item or article.

5

35. Use according to claim 34, wherein said item or article is chosen from the group of value documents, banknotes, passports, identity documents, driving licenses, official permissions, access documents, stamps, tax stamps and
10 banderoles, transportation tickets, event tickets, labels, foils, packaging, spare parts, and consumer goods.

36. Method for marking an item or article, said method comprising the steps of

15

- a) providing an item or article to be marked;
- b) applying at least one marking according to one of the claims 1 to 31 onto the said item or article in the form of indicia.

20 37. Method according to claim 36, wherein the unique code represented by the indicia is encrypted information, the method comprising the step of encrypting said information.

38. Method for authenticating an item or article, said method
25 comprising the steps of

30

- a) providing an item or article carrying a marking according to one of the claims 1 to 31;
- b) illuminating the marking on said article or item with at least one quality of light from at least one light source;
- c) detecting the said marking's determined optical characteristics through the sensing of light reflected by the marking;

d) determining the item's or article's authenticity from the detected optical characteristics of the marking.

5 39. Method according to claim 38, wherein the marking comprises a cholesteric liquid crystal material, exhibiting spectrally selective, viewing angle-dependent light reflection, the reflected light having a particular sense of circular polarization.

10

40. Method according to one of claims 38 to 39, wherein said light source is a spectrally selective light source.

15 41. Method according to claim 40, wherein said light source is chosen from the group of ambient light, incandescent light, laser diodes, light emitting diodes, and the light sources having color filters.

20 42. Method according to one of claims 38 to 41, wherein the light source is chosen to emit in a spectral domain of the group consisting of the visible (400-700nm wavelength), the near optical infrared (700-1100nm wavelength), the far optical infrared (1100-2500nm wavelength) and the UV (200-400nm wavelength) region of the electromagnetic spectrum.

25

43. Method according to one of claims 38 to 42, wherein said illuminating is performed by a light source chosen from the group consisting of the unpolarized, linear polarized, left circular polarized, and right circular polarized light sources.

30

44. Method according to one of claims 38 to 43, wherein at least two different said light sources are used in

conjunction.

45. Method according to one of claim 38 to 44, wherein said detecting is performed using at least one optical filter
5 chosen from the group consisting of the linear polarizing, left circular polarizing, right circular polarizing filters and the electro-optic polarization switches.
46. Method according to claim 45, wherein said optical filter
10 is combined with a color filter.
47. Method according to one of claims 45 to 46, wherein at least two different said optical filters are used in conjunction.
15
48. Method according to one of claims 38 to 47, wherein said detecting is performed by eye.
49. Method according to one of claims 38 to 47, wherein said
20 detecting is performed by an electro-optic detection equipment.
50. Method according to claim 49, wherein said electro-optic detecting equipment is chosen from the group consisting of
25 the photocells, linear CCD image sensor arrays, 2-dimensional CCD image sensor arrays, linear CMOS image sensor arrays, 2-dimensional CMOS image sensor arrays.
51. Method for identifying an item or article, said method
30 comprising the steps of
- a) providing an item or article carrying a marking according to one of the claims 1 to 31;
 - b) illuminating the marking on said article or item

with at least one quality of light from at least one light source;

c) reading the indicia represented by the marking, deriving corresponding information;

5 d) correlating the information retrieved from the indicia of the marking with information stored in a data base;

e) obtaining confirmation or denial concerning the item's or article's identity.

10

52. Method according to claim 51, comprising the further step of authenticating said item or article using the method according to one of claims 38 to 50.

15 53. Method according to one of claims 51 to 52, wherein the indicia are read with the help of an electro-optic image sensor array.

20 54. Method according to claims 53 wherein the electro-optic image sensor array is chosen from the group consisting of the linear CCD image sensor arrays, 2-dimensional CCD image sensor arrays, linear CMOS image sensor arrays, and 2-dimensional CMOS image sensor arrays.

25 55. Method according to one of claims 51 to 54, wherein information about the item or article is stored in the database.

30 56. Method according to one of claims 51 to 55, wherein the information exchange with the database takes place in encrypted form.

57. Method according to one of claims 51 to 56, wherein the

unique code represented by the indicia of the marking is encrypted information, the method comprising the step of decrypting said information.

- 5 58. Method for the secure tracking or tracing of an item or article, using a marking according to one of the claims 1 to 31, comprising the first commutable steps of
- a) applying a said marking to the item or article according to one of the claims 36 to 37;
 - 10 b) storing information related to the marked item or article in a data base;
- and the second commutable steps of
- c) authenticating the item or article according to one of the claims 38 to 50;
 - 15 d) identifying the item or article, according to one of the claims 51 to 57, using the information stored in the data base;
- and the optional step of
- e) updating the data base with new information elements
 - 20 related to the item or article.

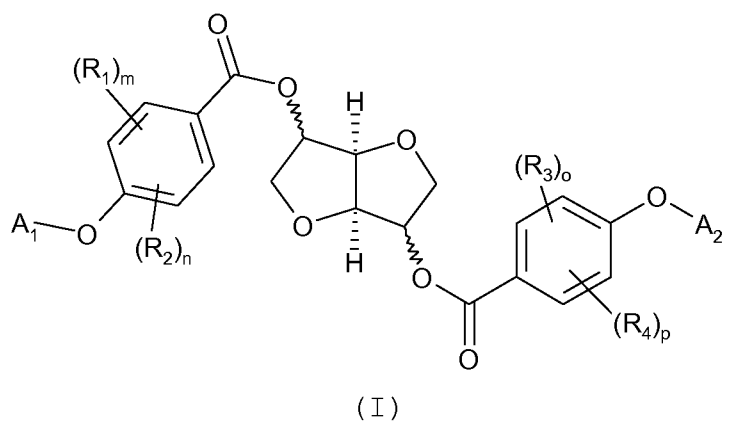
59. Method according to claim 58, wherein said item or article is chosen from the group of value documents, banknotes, passports, identity documents, driving licenses, official
- 25 permissions, access documents, stamps, tax stamps and banderoles, transportation tickets, event tickets, labels, foils, packaging, pharmaceutical products, spare parts, and consumer goods.

- 30 60. Intermediate in the liquid crystal state obtainable by independently applying a liquid crystal precursor composition to a substrate by a variable information printing process and applying heat to both evaporate the

solvent contained in the liquid crystal precursor composition and promote the liquid crystal state.

61. Intermediate according to claim 60 comprising a chiral
5 dopant according to formula (I).

62. A chiral dopant according to formula (I)



10

wherein

R_1 , R_2 , R_3 , R_4 , R_5 , R_6 , R_7 and R_8 denote each independently C_1 - C_6 alkyl, C_1 - C_6 alkoxy;

15

A_1 and A_2 denote each independently a group:

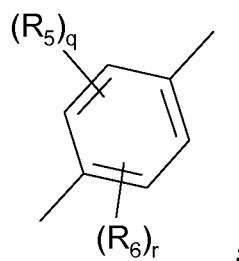
i) $-(CH_2)_y-O]z-C(O)-CH=CH_2$;

20

ii) $-C(O)-D_1-O-(CH_2)_y-O]z-C(O)-CH=CH_2$;

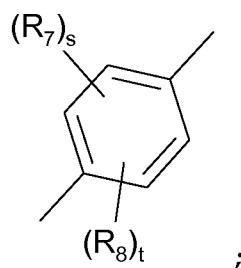
iii) $-C(O)-D_2-O-(CH_2)_y-O]z-C(O)-CH=CH_2$;

D_1 denotes a group



25

D_2 denotes a group

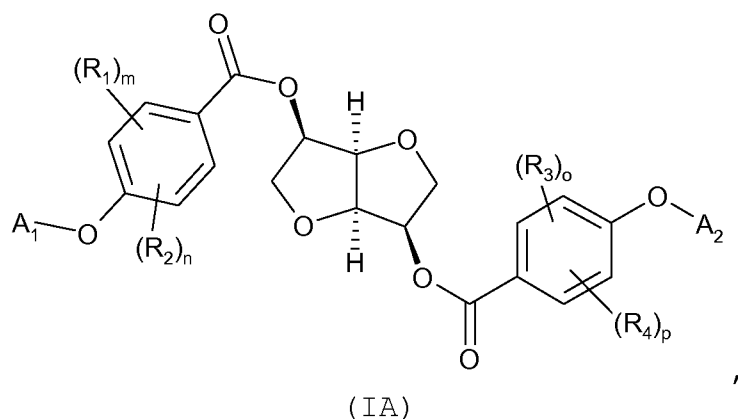


5 $m, n, o, p, q, r, s,$ and t denote each independently 0, 1, 2;

y denotes 0, 1, 2, 3, 4, 5, 6;

10 z equal 0 if y equal 0 and z equal 1 if y equal 1 to 6.

63. A chiral dopant according to formula (IA)



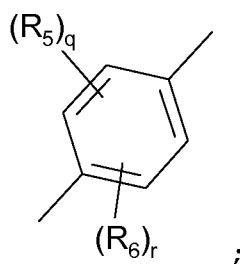
wherein

20 $R_1, R_2, R_3, R_4, R_5, R_6, R_7$ and R_8 denote each independently C_1 - C_6 alkyl, C_1 - C_6 alkoxy;

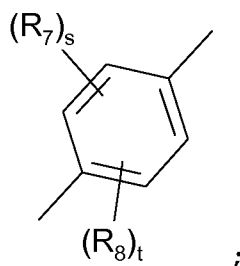
A_1 and A_2 denote each independently a group:

- 25 i) $-(CH_2)_y-O]z-C(O)-CH=CH_2$;
 ii) $-C(O)-D_1-O-[(CH_2)_y-O]z-C(O)-CH=CH_2$;
 iii) $-C(O)-D_2-O-[(CH_2)_y-O]z-C(O)-CH=CH_2$;

30 D_1 denotes a group



D₂ denotes a group



5

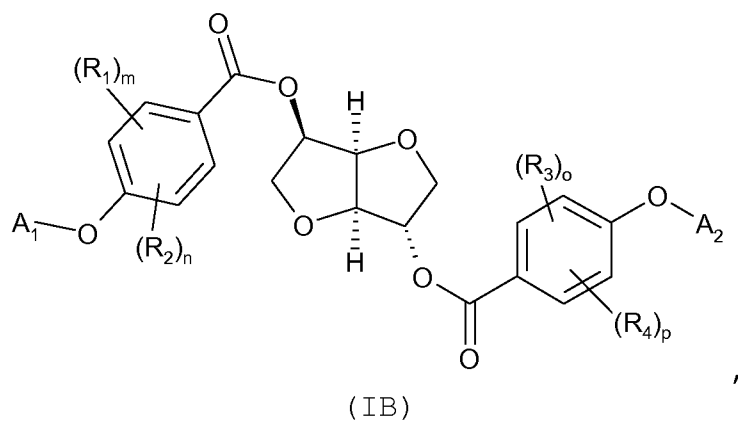
m, n, o, p, q, r, s, and t denote each independently 0, 1, 2;

10

y denotes 0, 1, 2, 3, 4, 5, 6;

z equal 0 if y equal 0 and z equal 1 if y equal 1 to 6.

64. A chiral dopant according to formula (IB)



15

wherein

20

R₁, R₂, R₃, R₄, R₅, R₆, R₇ and R₈ denote each independently C₁-C₆ alkyl, C₁-C₆ alkoxy;

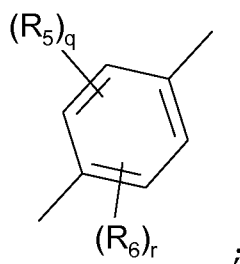
A₁ and A₂ denote each independently a group:

i) $-\text{[(CH}_2\text{)}_y\text{-O]}_z\text{-C(O)-CH=CH}_2$;

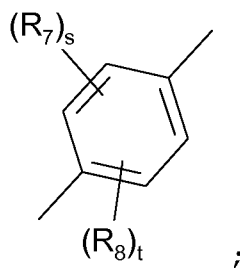
ii) $-\text{C(O)-D}_1\text{-O-[(CH}_2\text{)}_y\text{-O]}_z\text{-C(O)-CH=CH}_2$;

5 iii) $-\text{C(O)-D}_2\text{-O-[(CH}_2\text{)}_y\text{-O]}_z\text{-C(O)-CH=CH}_2$;

D₁ denotes a group



10 D₂ denotes a group



15 m, n, o, p, q, r, s, and t denote each independently 0, 1, 2;

y denotes 0, 1, 2, 3, 4, 5, 6;

z equal 0 if y equal 0 and z equal 1 if y equal 1 to 6.

20

65. A chiral dopant according to claim 63 or 64, wherein R₁, R₂, R₃, R₄, R₅, R₆, R₇ and R₈ denote each independently C₁-C₆ alkyl.

25 66. A chiral dopant according to claim 63 or 64, wherein R₁, R₂, R₃, R₄, R₅, R₆, R₇ and R₈ denote each independently C₁-C₆ alkoxy.

30 67. A chiral dopant according to claim 63 or 64, wherein A₁ and A₂ denote each independently i) $-\text{[(CH}_2\text{)}_y\text{-O]}_z\text{-C(O)-CH=CH}_2$; R₁,

R_2 , R_3 and R_4 denote each independently C_1 - C_6 alkyl or C_1 - C_6 alkoxy; and m , n , o , and p denote each independently 0, 1, 2.

- 5 68. A chiral dopant according to claim 63 or 64, wherein A_1 and A_2 denote each independently ii) $-C(O)-D_1-O-[(CH_2)_y-O]_z-C(O)-CH=CH_2$ and/or iii) $-C(O)-D_2-O-[(CH_2)_y-O]_z-C(O)-CH=CH_2$; and R_1 , R_2 , R_3 , R_4 , R_5 , R_6 , R_7 and R_8 denote each independently C_1 - C_6 alkyl or C_1 - C_6 alkoxy.

10

69. A chiral dopant according to claim 63 or 64, wherein the alkyl or alkoxy group of R_1 , R_2 , R_3 , R_4 , R_5 , R_6 , R_7 and R_8 may comprise 4 or 6 carbon atoms.