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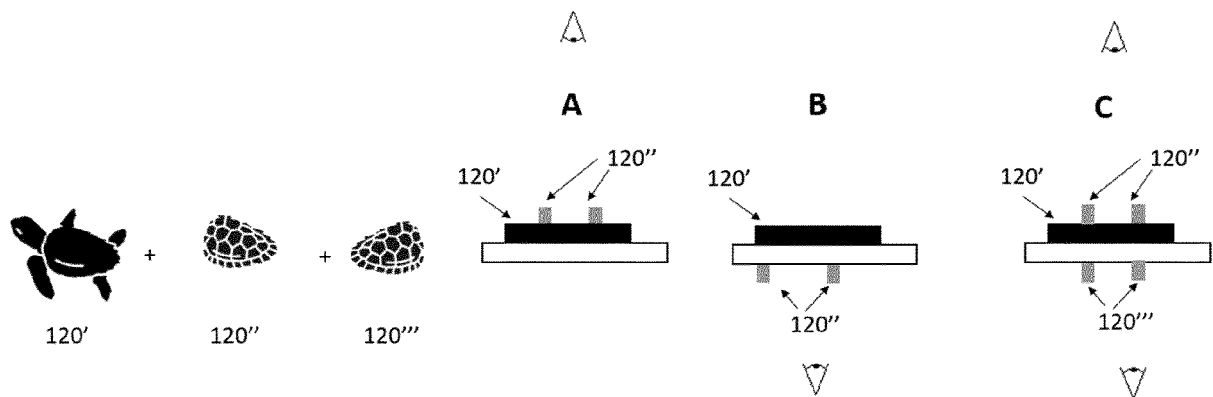
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PROCESSES FOR PRODUCING OPTICAL EFFECTS LAYERS

- (57)

The invention relates to the field of the protection of security documents such as for example banknotes and identity documents against counterfeit and illegal re-production. In particular, the present invention provides
- processes for producing optical effect layers (OELs) comprising at least a first motif and a second motif, each of said motifs independently comprising platelet-shaped magnetic or magnetizable pigment particles.

Fig. 1



Description**FIELD OF THE INVENTION**

[0001] The present invention relates to the field of processes for producing optical effect layers (OELs) comprising magnetically oriented platelet-shaped magnetic or magnetizable pigment particles. In particular, the present invention provides processes for magnetically orienting platelet-shaped magnetic or magnetizable pigment particles in more than one coating layers so as to produce OELs and the use of said OELs as anti-counterfeit means on security documents or security articles as well as decorative purposes.

BACKGROUND OF THE INVENTION

[0002] It is known in the art to use inks, compositions, coatings or layers containing oriented magnetic or magnetizable pigment particles, particularly also optically variable magnetic or magnetizable pigment particles, for the production of security elements, e.g. in the field of security documents. Coatings or layers comprising oriented magnetic or magnetizable pigment particles are disclosed for example in US 2,570,856; US 3,676,273; US 3,791,864; US 5,630,877; and US 5,364,689. Coatings or layers comprising oriented magnetic color-shifting pigment particles, resulting in particularly appealing optical effects, useful for the protection of security documents, have been disclosed in WO 2002/090002 A2 and WO 2005/002866 A1.

[0003] Security features, e.g. for security documents, can generally be classified into "covert" security features on the one hand, and "overt" security features on the other hand. The protection provided by covert security features relies on the principle that such features are difficult to detect, typically requiring specialized equipment and knowledge for detection, whereas "overt" security features rely on the concept of being easily detectable with the unaided human senses, e.g. such features may be visible and/or detectable via the tactile sense while still being difficult to produce and/or to copy. However, the effectiveness of overt security features depends to a great extent on their easy recognition as a security feature.

[0004] Overt features in the forms of foils or patches comprising holograms, lenticular structures and arrays of microlenses and micromirrors have been widely used in security documents, in particular banknotes. These security features are produced separately and integrated into the security document during its production. Foils and patches are produced on reels of substrate by several techniques selected from the group of printing, coating, vapor deposition, etching, varnishing and/or combination thereof, which are finally sliced into foils and patches to be inserted into the security document substrates during their production and are applied by gluing or by hot-stamping onto the security document substrates. These structures can be integrated in windowed security threads, security foils, security patches, or applied, e.g. by hot-stamping, as such to the security document substrate for e.g. on a transparent window of a security document.

[0005] Said security features are said to be highly eye-catching features due to their high brightness having often a metallic aspect. Said security features are particularly suitable to be applied on foils and windows of value documents, in particular banknotes. Due to the highly demanding application of protecting value documents, in particular banknotes, said security features exhibit poor chemical and physical resistance during their exposure to the environment and conditions such as those met during circulation of valued documents carrying those security features, thus leading to their premature deterioration.

[0006] With the aim of optimizing and increasing the counterfeiting resistance of security documents, in particular banknotes, striking and sophisticated magnetically induced images and optical effects layers (OELs) have been developed. Magnetic or magnetizable pigment particles in printing inks or coatings allow for the production of magnetically induced images, designs and/or patterns (also referred in the art as "Optical Effect Layers (OELs)") through the application of a correspondingly structured magnetic field, inducing a local orientation of the magnetic or magnetizable pigment particles in the not yet hardened (i.e. wet) coating, followed by the hardening of the coating. The result is a fixed and stable magnetically induced image, design or pattern. Materials and technologies for the orientation of magnetic or magnetizable pigment particles in coating compositions are known. The magnetically induced images in question can only be produced by having access to both, the magnetic or magnetizable pigment particles or the corresponding ink, and the particular technology employed to print said ink and to orient said pigment in the printed ink. Said OELs are obtained by using specific magnetic assemblies and advantageously exhibit a dynamic appearance upon tilting. Examples of such dynamic OELs include reflection zone bars moving as the OEL is tilted, loop-shaped bodies moving as the OEL is tilted, loop-shaped bodies having a varying shape as the OEL is tilted, bright areas and dark areas moving as the OEL is tilted. WO 2012/104098 A1 discloses OELs comprising more than one magnetically induced images. WO 2012/104098 A1 discloses an OEL comprising two areas, each one exhibiting a reflection zone bar moving as the OEL is tilted, one of said bar moving away the observer upon tilting of the OEL and the other said bar moving towards the observer upon tilting of the OEL.

[0007] A need remains for improved processes for producing eye-catching and highly bright overt security features

for security printers at industrial speed, wherein said so-produced security features are easily authenticated by the man in the street, are resistant to chemical and physical stress conditions borne by a security document or article comprising said features while said processes are highly difficult to be implemented on a mass-scale production by counterfeiters and the illicit market.

SUMMARY OF THE INVENTION

[0008] Accordingly, it is an object of the present invention to overcome the deficiencies of the prior art as discussed above. This is achieved by the provision of a process for producing an optical effect layer (OEL) on a substrate (x10), said optical effect layer (OEL) comprising a first motif comprising magnetically oriented platelet-shaped magnetic or magnetizable pigment particles oriented according to a first magnetic pattern and a second motif comprising magnetically oriented platelet-shaped magnetic or magnetizable pigment particles oriented according to a second magnetic pattern, said process comprising:

a first set of steps consisting of

- a') applying onto the substrate (x10) a first radiation curable coating composition, preferably a first UV-Vis-curable coating composition, comprising the platelet-shaped magnetic or magnetizable pigment particles so as to form a first coating layer (x20') on said the substrate (x10), said coating composition being in a first state;
- b') exposing the first radiation curable coating composition of step a') to a magnetic field of a magnetic assembly (x30') so as to magnetically orient at least a part of the platelet-shaped magnetic or magnetizable pigment particles;
- c') at least partially curing the first radiation curable coating composition of step b') to a second state so as to fix the platelet-shaped magnetic or magnetizable pigment particles in their adopted positions and

orientations and so as to produce the first motif; and
a second set of steps consisting of

- a'') applying in register a second radiation curable coating composition, preferably a second UV-Vis-curable coating composition, comprising platelet-shaped magnetic or magnetizable pigment particles so as to form a second coating layer (x20''), said coating composition being in a first state, and at least a part of the second coating layer (x20'') being adjacent to at least a part of the first coating layer (x20');
- b'') exposing the second radiation curable coating composition of step a'') to a magnetic field of a magnetic assembly (x30'') so as to bi-axially orient at least a part of the platelet-shaped magnetic or magnetizable pigment particles to i) have both their X-axis and Y-axis substantially parallel to the substrate (x10) surface, or ii) have their X-Y plane parallel to an imaginary spheroid surface;
- c'') at least partially curing the second radiation curable coating composition of step b'') to a second state so as to fix the platelet-shaped magnetic or magnetizable pigment particles in their adopted positions and orientations and so as to produce the second motif.

[0009] Also described herein are processes for producing OELs comprising the first motif comprising the platelet-shaped magnetic or magnetizable pigment particles oriented according to the first magnetic pattern described herein, the second motif comprising the platelet-shaped magnetic or magnetizable pigment particles oriented according to the second magnetic pattern described herein, and a third motif comprising the platelet-shaped magnetic or magnetizable pigment particles oriented according to a third magnetic pattern, wherein the first and second motifs are different from each other and wherein the third and second patterns may be the same or different from each other, wherein the third motif is adjacent to and in proper register with at least a part of the first motif and/or adjacent to and in proper register with at least a part of the second motif (i.e. the third motif is at least partially adjacent to and in proper register with the first motif and/or at least partially adjacent to and in proper register with the second motif), and wherein said processes comprise the first set of steps (S1) a'), b') and c') described herein, the second set of steps (S2) a''), b'') and c'') described herein and a third set of steps (S3) a'''), b''') and c'''), said third step a''') being carried out subsequently to and continuously with step c'').

[0010] The OELs described herein comprises at least the first and second motifs described herein, i.e. the OELs described herein may comprise a third motif, a fourth motif, etc., provided that at least one motif outmost facing the environment comprises magnetically oriented platelet-shaped magnetic or magnetizable pigment particles oriented according to a magnetic pattern, wherein said particles have i) have both their X-axis and Y-axis substantially parallel to the substrate (x10) surface, or ii) have their X-Y plane parallel to an imaginary spheroid surface.

[0011] Also described herein are optical effect layers (OELs) produced by the process described herein and security

documents as well as decorative elements and objects comprising one or more optical OELs described herein.

[0012] Also described herein are methods of manufacturing a security document or a decorative element or object, comprising a) providing a security document or a decorative element or object, and b) providing an optical effect layer (OEL) obtained by the process described herein, so that it is comprised by the security document or decorative element or object.

[0013] The present invention provides processes advantageously allowing the manufacture of eye-catching highly bright optical effect layers (OELs) which are easily authenticated by the man in the street. The so-produced optical effect layers (OELs) made from security inks comprising magnetically oriented pigment particles according to specific magnetic patterns are highly bright, reflective, metallic shiny and dynamic when observed from the side of the substrate carrying at least the second coating layer and are thus particularly attractive for the protection of security documents, in particular banknotes, due to the combined eye-catching optical effect, their resistance against physical and chemical attacks from the environment and the high design flexibility to produce them.

BRIEF DESCRIPTION OF DRAWINGS

[0014]

Figs 1-13 provided therein schematically illustrates the present invention and are not true to scale. The optical effect layers (OELs) described herein and their production are now described in more detail with reference to the drawings and to particular embodiments, wherein

Figs 1A-B schematically illustrates the combination of a first motif comprising platelet-shaped magnetic or magnetizable pigment particles oriented according to a first magnetic pattern and a second motif comprising platelet-shaped magnetic or magnetizable pigment particles oriented according to a second magnetic pattern, wherein the first and second motifs are either on the same side of the substrate (Fig. 1A) or on opposite sides (Fig. 1B), wherein said OEL is highly bright, in particular highly bright and dynamic, when observed from the side carrying the second motif (120") (see eye in Figs. 1A-B).

Fig. 1C schematically illustrates the combination of a first motif comprising platelet-shaped magnetic or magnetizable pigment particles oriented according to a first magnetic pattern, a second motif comprising platelet-shaped magnetic or magnetizable pigment particles oriented according to a second magnetic pattern and a third motif comprising platelet-shaped magnetic or magnetizable pigment particles oriented according to a third magnetic pattern, wherein the first and second motifs are on the same side of the substrate (110) and the third motif is on the opposite side of the substrate (110), wherein said OEL is highly bright, in particular highly bright and dynamic, when observed from the side carrying the second motif (120") and/or from the side carrying the third motif (120") (see eyes in 1C).

Fig. 2 schematically illustrates a platelet-shaped pigment particle.

Fig. 3A schematically illustrates a first set of steps (S1) described herein, wherein the orientation step b') is a one-step orientation step and wherein a substrate (310) carrying a first coating layer (320') obtained by screen printing (340') (step a')) is exposed to the magnetic field of a magnetic assembly (330') and wherein the first coating layer (320') is, partially simultaneously with step b'), at least partially cured with a first curing unit (350') (step c')).

Figs 3B and 3C illustrate an industrial one-step orientation step steps b') shown in Fig. 3, wherein the first coating layer (320') is exposed to the magnetic field of a magnetic assembly (330') being either mounted on a rotating magnetic cylinder with the first coating layer (320') facing the environment (Fig. 3B) or placed outside a rotating cylinder with the first coating layer (320') facing said magnetic assembly (330') (Fig. 3C) and wherein the first coating layer (320') is, partially simultaneously with step b'), at least partially cured with a curing unit (350') (step c')).

Fig. 4A illustrates a first set of steps (S1) described herein, wherein the orientation step b') is a one-step orientation step wherein the first coating layer (420') is exposed to the resultant magnetic field of a first magnetic assembly (430'-a) and of a second magnetic assembly (430'-b), and wherein the first coating layer (420') is, partially simultaneously with step b'), at least partially cured with a first curing unit (450') (step c')).

Fig. 4B illustrates an industrial one-step orientation step b') shown in Fig. 4A, wherein the first coating layer (420') is exposed to the resultant magnetic field of a first magnetic assembly (430'-a) and of a second magnetic assembly (430'-b), wherein said first magnetic assembly (430'-a) is mounted on a rotating magnetic cylinder and the second magnetic assembly (430'-b) is placed outside the rotating magnetic cylinder and wherein the first coating layer (420') is, partially simultaneously with step b'), at least partially cured with a curing unit (450') (step c')).

Fig. 5A schematically illustrates a first set of steps (S1) described herein, wherein the orientation step b') is a two-steps orientation step and wherein a substrate (510) carrying a first coating layer (520') obtained by screen printing (540') (step a')) is first exposed to a first magnetic field of a magnetic assembly (530'-a) (step b'-1)) and then subsequently exposed to a second magnetic field of a magnetic assembly (530'-b) (step b'-2)) so as to re-orient the pigment particles (step b')) and wherein the first coating layer (520') is, partially simultaneously with step b') at least partially cured with a first curing unit (550') (step c')).

Fig. 5B illustrates an industrial two-steps orientation step b') shown in Fig. 5A, wherein the first coating layer (520') is first exposed to the magnetic field of a first magnetic assembly (530'-a) and subsequently to the magnetic field of a second magnetic assembly (530'-b), wherein said first magnetic assembly (530'-a) is placed outside and before a rotating magnetic cylinder and said second magnetic assembly (530'-b) is mounted on said rotating magnetic cylinder and wherein the first coating layer (520') is, partially simultaneously with step b'), at least partially cured with a curing unit (550') (step c')).

Fig. 6A schematically illustrates a first set of steps (S1) described herein, wherein the orientation step b') is a two-steps orientation step and wherein a substrate (610) carrying a first coating layer (620') obtained by screen printing (640') (step a')) is first exposed to a first magnetic field of a magnetic assembly (630'-a) (step b'-1)) and then subsequently exposed to the resultant magnetic field of a second magnetic assembly (630'-a) and of a third magnetic assembly (630'-c) (step b'-2)) and wherein the coating layer (620') is, partially simultaneously with step b') at least partially cured with a first curing unit (650') (step c')).

Fig. 6B illustrates an industrial two-steps orientation step b') shown in Fig. 6A, wherein the coating layer (620') is first exposed to the magnetic field of a first magnetic assembly (630'-a) and subsequently to the resultant magnetic field of a second magnetic assembly (630'-b) and of a third magnetic assembly (630'-c), wherein said first magnetic assembly (630'-a) is placed outside a rotating magnetic cylinder, said second magnetic assembly (630'-b) is mounted on said rotating magnetic cylinder and said third magnetic assembly (630'-c) is placed outside said rotating magnetic cylinder and wherein the first coating layer (620') is, partially simultaneously with step b') at least partially cured with a curing unit (650') (step c')).

Fig 7A schematically illustrates a second set of steps (S2) described herein, wherein the orientation step b'') is a one-step orientation step and wherein a substrate (710) carrying a first coating layer (720') and a second coating layer (720'') obtained by screen printing (740'') (step a'')) on the same side as the first coating layer (720') is exposed to the magnetic field of a magnetic assembly (730'') so as to bi-axially orient the pigment particles and wherein the second coating layer (720'') is, partially simultaneously with step b''), at least partially cured with a second curing unit (750'') (step c'')).

Fig. 7B schematically illustrates a second set of steps (S2) described herein, wherein the orientation step b'') is a one-step orientation step and wherein a substrate (710) carrying a first coating layer (720') and a second coating layer (720'') obtained by screen printing (740'') (step a'')) on the side of the substrate (710) lacking the first coating layer (720') is exposed to a magnetic field of a magnetic assembly (730'') so as to bi-axially orient the pigment particles and wherein the second coating layer (720'') is, partially simultaneously with step b''), at least partially cured with a second curing unit (750'') (step c'')).

Fig. 7C illustrates a one-step industrial orientation step b'') shown in Fig. 7A, wherein the second coating layer (720'') is exposed to the magnetic field of a magnetic assembly (730''), wherein said magnetic assembly (730'') is placed outside a rotating cylinder (two alternative positions are shown in Fig. 7C) and wherein the second coating layer (720'') is at least partially cured with a curing unit (750') (step c'')).

Fig. 8A schematically illustrates a second set of steps (S2) described herein, wherein the orientation step b'') is a one-step orientation step and wherein a substrate (810) carrying a first coating layer (820') and a second coating layer (820'') obtained by screen printing (840'') (step a'')) on the same side as the first coating layer (820') is exposed to a magnetic field of a spinning magnetic assembly (830'') so as to bi-axially orient the pigment particles (step b'') and wherein the second coating layer (820'') is, partially simultaneously with step b''), at least partially cured with a second curing unit (850'') (step c'')).

Fig. 8B schematically illustrates a second set of steps (S2) described herein, wherein the orientation step b'') is a one-step orientation step and wherein a substrate (810) carrying a first coating layer (820') and a second coating layer (820'') obtained by screen printing (840'') (step a'')) on the side of the substrate (810) lacking the first coating layer (820') is exposed to a magnetic field of a spinning magnetic assembly (830'') so as to bi-axially orient the pigment particles (step b'') and wherein the second coating layer (820'') is, partially simultaneously with step b''), at least partially cured with a second curing unit (850'') (step c'')).

Fig. 8C illustrates a one-step industrial orientation step b'') shown in Fig. 8A, wherein the second coating layer (820'') is exposed to the magnetic field of a spinning magnetic assembly (830''), wherein said magnetic assembly (830'') is mounted on a rotating magnetic cylinder and wherein the second coating layer (820'') is, partially simultaneously with step b''), at least partially cured with a curing unit (850'') (step c'')).

Fig. 9 schematically illustrates a third set of steps (S3) described herein occurring after the second set of steps (S2), wherein the orientation step b''') is a one-step orientation step and wherein a substrate (910) carrying a first and second coating layers (920' and 920'') and a third coating layer (920''') obtained by screen printing (940''') (step a''') on the opposite side as the first and second coating layers (920' and 920'') is exposed to a magnetic field of a spinning magnetic assembly (930''') so as to bi-axially orient the pigment particles (step b''') and wherein the third coating layer (920''') is, partially simultaneously with step b'''), at least partially cured with a third curing unit (950''') (step c''').

Fig. 10 schematically illustrates a magnetic assembly (1030) for bi-axially orienting the pigment particles used in step b') of the Examples E1-E5 and in step b") of the Example E1 provided therein.

Fig. 11 schematically illustrates a magnetic assembly (1130) used in step b') of the Example E1-E5 provided therein and being suitable for producing a motif exhibiting a dynamic movement of a reflective bar moving when the motif is tilted.

Fig. 12 schematically illustrates a magnetic assembly (1230) for bi-axially orienting the pigment particles and used in step b") of the Examples E2 and E4 and in step b''') of the Example E4 provided therein.

Fig. 13 schematically illustrates a magnetic assembly (1330) for bi-axially orienting the pigment particles used in step b") of the Examples E3 and E5 and in step b''') of the Example E5 provided therein.

[0015] The distances provided in the Figures are only illustrative and not true to scale.

DETAILED DESCRIPTION

Definitions

[0016] The following definitions are to be used to interpret the meaning of the terms discussed in the description and recited in the claims.

[0017] As used herein, the indefinite article "a" indicates one as well as more than one and does not necessarily limit its referent noun to the singular.

[0018] As used herein, the term "at least" is meant to define one or more than one, for example one or two or three.

[0019] As used herein, the term "about" means that the amount or value in question may be the specific value designated or some other value in its neighborhood. Generally, the term "about" denoting a certain value is intended to denote a range within $\pm 5\%$ of the value. As one example, the phrase "about 100" denotes a range of 100 ± 5 , i.e. the range from 95 to 105. Generally, when the term "about" is used, it can be expected that similar results or effects according to the invention can be obtained within a range of $\pm 5\%$ of the indicated value.

[0020] As used herein, the term "and/or" means that either all or only one of the elements of said group may be present. For example, "A and/or B" shall mean "only A, or only B, or both A and B". In the case of "only A", the term also covers the possibility that B is absent, i.e. "only A, but not B".

[0021] The term "comprising" as used herein is intended to be non-exclusive and open-ended. Thus, for instance a coating composition comprising a compound A may include other compounds besides A. However, the term "comprising" also covers, as a particular embodiment thereof, the more restrictive meanings of "consisting essentially of" and "consisting of", so that for instance "a fountain solution comprising A, B and optionally C" may also (essentially) consist of A and B, or (essentially) consist of A, B and C.

[0022] The term "optical effect layer (OEL)" as used herein denotes a coating or layer that comprises oriented platelet-shaped magnetic or magnetizable pigment particles and a binder, wherein said platelet-shaped magnetic or magnetizable pigment particles are oriented by a magnetic field and wherein the oriented platelet-shaped magnetic or magnetizable pigment particles are fixed/frozen in their orientation and position (i.e. after hardening/curing) so as to form a magnetically induced image.

[0023] The term "coating composition" refers to any composition which is capable of forming an optical effect layer (EOL) on a solid substrate and which can be applied preferably but not exclusively by a printing method. The coating composition comprises the platelet-shaped magnetic or magnetizable pigment particles described herein and the binder described herein.

[0024] As used herein, the term "wet" refers to a coating layer which is not yet cured, for example a coating in which the platelet-shaped magnetic or magnetizable pigment particles are still able to change their positions and orientations under the influence of external forces acting upon them.

[0025] As used herein, the term "indicia" shall mean discontinuous layers such as patterns, including without limitation symbols, alphanumeric symbols, motifs, letters, words, numbers, logos and drawings.

[0026] The term "curing" is used to denote a process wherein the viscosity of a coating composition in a first physical state which is not yet hardened (i.e. wet) is increased so as to convert it into a second physical state, i.e. a hardened or solid state, where the platelet-shaped magnetic or magnetizable pigment particles are fixed/frozen in their current positions and orientations and can no longer move nor rotate.

[0027] The term "security document" refers to a document which is usually protected against counterfeit or fraud by at least one security feature. Examples of security documents include without limitation value documents and value commercial goods.

[0028] The term "security feature" is used to denote an image, pattern or graphic element that can be used for authentication purposes.

[0029] Where the present description refers to "preferred" embodiments/features, combinations of these "preferred"

embodiments/features shall also be deemed as disclosed as long as this combination of "preferred" embodiments/features is technically meaningful.

[0030] The present invention provides processes for producing optical effect layers (OELs) being suitable as security features against counterfeit or fraud and comprising magnetically oriented platelet-shaped magnetic or magnetizable pigment particles on substrates. As shown in Figs 1A-B, said OELs comprise a first motif (in the form of a cured first coating layer 120') comprising platelet-shaped magnetic or magnetizable pigment particles oriented according to a first magnetic pattern and a second motif (in the form of a cured second coating layer 120'') comprising platelet-shaped magnetic or magnetizable pigment particles oriented according to a second magnetic pattern, wherein said first and second motifs are at least partially adjacent to each other (i.e. the second motif is adjacent to at least a part of the first motif) and in proper register.

[0031] As shown in Fig. 1C, said OELs comprise a first motif (in the form of a cured first coating layer 120') comprising platelet-shaped magnetic or magnetizable pigment particles oriented according to a first magnetic pattern, a second motif (in the form of a cured second coating layer 120'') comprising platelet-shaped magnetic or magnetizable pigment particles oriented according to a second magnetic pattern, and a third motif (in the form of a cured third coating layer 120''') comprising platelet-shaped magnetic or magnetizable pigment particles oriented according to a third magnetic pattern wherein at least a part of the third motif is adjacent to at least a part of the first motif and in proper register and/or adjacent to at least a part of the second motif and in proper register (i.e. the third motif is at least partially adjacent to and in proper register with the first motif and/or at least partially adjacent to and in proper register with the second motif), preferably adjacent to and in proper register with at least a part of the first motif and adjacent to and in proper register with at least a part of the second motif (i.e. at least partially adjacent to and in proper register with the first motif and at least partially adjacent to and in proper register with the second motif).

[0032] The first and second motifs (in the form of a cured first coating layer (x20')' and second coating layer (20'')) may independently consist of single sub-motifs or may, as shown in Figs 1, consist of more than one sub-motifs, said more than one sub-motifs independently forming the first and second motifs, respectively. Should the first and/or second motifs described herein independently consist of sub-first-motifs and sub-second-motifs (as shown for example in Figs 1), the OEL results from the combination of a plurality or of all sub-motifs.

[0033] As described herein, the first magnetic pattern of the first motif and the second magnetic pattern of the second motif are obtained by independently exposing the first radiation curable coating composition of step a') and the second radiation curable coating composition of step a'') to the magnetic field of a magnetic assembly (x30') during step b') so as to magnetically orient at least a part of the platelet-shaped magnetic or magnetizable pigment particles and to the magnetic field of a magnetic assembly (x30'') during step b'') so as to bi-axially orient at least a part of the platelet-shaped magnetic or magnetizable pigment particles.

[0034] The process described herein comprises at least two sets of steps, i.e. a first set (S1) comprising steps a'), b') and c') and a second set (S2) comprising steps a''), b'') and c'') (optionally a third set of steps (S3) comprising a'''), b''') and c'''), optionally a fourth set of steps (S4) comprising a'''), b''') and c'''), etc.), wherein the last set of steps consists of bi-axially orienting at least a part of the platelet-shaped magnetic or magnetizable pigment particles so that they i) have both their X-axis and Y-axis substantially parallel to the substrate (x10) surface, or ii) have their X-Y plane parallel to an imaginary spheroid surface. For embodiments comprising three set of steps, preferably the step b') of the first set (S1) consists of orienting the at least a part of the pigment particles so that the first motif exhibit a dynamic effect, the step b'') of the second set (S2) and the step b''') of the last set (S3) consist of bi-axially orienting at least a part of the pigment particles so that they i) have both their X-axis and Y-axis substantially parallel to the substrate (x10) surface, or ii) have their X-Y plane parallel to an imaginary spheroid surface, alternatively for embodiments comprising three set of steps, preferably the step b') of the first set (S1) consists of orienting the at least a part of the pigment particles so that the first motif exhibits a dynamic effect, the step b'') of the first set (S2) consists of orienting the at least a part of the pigment particles so that second motif exhibits a dynamic effect and the step b''') of the last set (S3) consists of bi-axially orienting at least a part of the pigment particles so that they i) have both their X-axis and Y-axis substantially parallel to the substrate (x10) surface, or ii) have their X-Y plane parallel to an imaginary spheroid surface; for embodiments comprising n set of steps, preferably, the step b⁽ⁿ⁻¹⁾) of the (n-1) set (S(n-1)) and the step bⁿ) of the last set (S_n) consists of bi-axially orient at least a part of the pigment particles so that they i) have both their X-axis and Y-axis substantially parallel to the substrate (x10) surface, or ii) have their X-Y plane parallel to an imaginary spheroid surface. The process described herein is thus a continuous process meaning that the second set of steps (S2) is carried out directly after the first set (S1) (in other words, the step a'') of the second set is carried out subsequently and directly after step c') of the first set), for embodiments comprising n set of steps, the step aⁿ) of the n set (S(n)) is carried out subsequently and directly after step c⁽ⁿ⁻¹⁾) of the (n-1)th set. In other words, the multi-sets of steps process described herein is a continuous process using a single machine, said machine allowing the application, preferably printing, of coating compositions, the exposure of said compositions to magnetic fields and the at least partial curing of said compositions, said process allowing the preparation of OELs comprising the first motif and the second motif described herein being at least partially adjacent to each other (i.e. the second motif is adjacent to at least a part of the first motif) and in proper register, wherein

an observer sees a highly bright effect, preferably highly bright and dynamic effect wherein said first motif and second motif are at least partially adjacent to each other (i.e. the second motif is adjacent to at least a part of the first motif) and in proper register.

[0035] As shown in Figs 1A-B, the OEL described herein comprises the first and second motifs (i.e. the first and second cured coating layers 120' and 120") on the same side of the substrate (110) (see Fig. 1 A) or on the opposite side of the substrate (110) (i.e. the side of the substrate lacking the first motif) (see Fig. 1 B), wherein said substrate (110) is preferably transparent, and wherein said first and second motifs are at least partially adjacent to each other (i.e. the second motif is adjacent to at least a part of the first motif) and in proper register so that an observer sees the OEL as highly bright (when observed from the side of the substrate (110) carrying the first and second coating layers (120' and 120") in Fig. 1A or when observed from the side of the substrate (110) carrying the second layer (120") in Fig. 1B, see the eye in Figs 1A-B) and sees said OEL as a bright continuous feature in a see-through observation mode, in a reflection observation mode or in a transparency observation mode.

[0036] As shown in Fig. 1C, the OEL described herein comprises the first, second and third motifs (i.e. the first, second and third cured coating layers 120', 120" and 120""), wherein the first and second motifs (120' and 120") are on the same sides of the substrate (110) and the third motif (120'') is on the side of the substrate (110) lacking the first motif (120') and lacking the second motif (120"), wherein said substrate (110) is preferably transparent, and wherein said first and second motifs are at least partially adjacent to each other (i.e. the second motif is adjacent to at least a part of the first motif) and in proper register and the third motif is at least partially adjacent to and in proper register with the first motif and/or at least partially adjacent to and in proper register with the second motif (i.e. the third motif at least partially adjacent to and in proper register with the first motif and at least partially adjacent and in proper register with the second motif in Fig. 1C) so that an observer sees the OEL as highly bright (when observed from the side of the substrate (110) carrying the first and second coating layers (120' and 120") and/or when observed from the side of the substrate (110) carrying the third layer (120'') in Fig. 1C, see the eye in Figs 1C) and sees said OEL as a continuous feature in a see-through observation mode, in a reflection observation mode or in a transparency observation mode.

[0037] By "adjacent", it means that the first and second motifs are superimposed, encompassing that the second coating layer (x20") is in direct contact with the first coating layer (x20') (see Figs 1A and 1C) as well as that the second coating layer (x20") is in direct contact with the first coating layer (x20') through the substrate (i.e. the substrate is present therebetween and they are in indirect contact) (see Fig. 1B). In other words, the second motif is present on top of and in direct contact with the first motif or the second motif faces the first motif through the substrate.

[0038] The process described herein comprises at least two independent steps a') and a") consisting of applying the first radiation curable coating composition so as to form the first coating layer (x20') (step a') and consisting of applying in register the second radiation curable coating composition so as to form the second coating layer (x20") (step a"), wherein said first and second radiation curable coating compositions are in a first physical state which allows their application as layers and which are in a not yet hardened (i.e. wet) state wherein the platelet-shaped magnetic or magnetizable pigment particles can move and rotate within the binder material.

[0039] By applying in register in step a"), it is meant that the radiation curable coating composition is applied without or with a very limited (smaller than 1 mm, preferably smaller than 0.5 mm, more preferably smaller than or equal to 0.2 mm) misalignment and misplacement between the second coating layer (x20") and the first coating layer (x20') so that the obtained OEL appears to the naked eye as a continuous layer (i.e. no breakup image). Said application in register is allowed by the claimed continuous process using a single machine. According to one embodiment, the first and second coating layers (x20' and x20") are applied within a register of ± 1 mm, preferably ± 0.5 mm and more preferably ± 0.2 mm. Said application in register is allowed by the claimed continuous process using a single machine.

[0040] Preferably, said steps a') and a") are independently carried out by a printing process, preferably independently selected from the group consisting of screen printing, rotogravure printing, flexography printing and intaglio printing (also referred in the art as engraved copper plate printing and engraved steel die printing), more preferably selected from the group consisting of screen printing, rotogravure printing and flexography printing and still more preferably by screen printing.

[0041] Screen printing (also referred in the art as silkscreen printing) is a stencil process wherein an ink is transferred to a surface through a stencil supported by a fine fabric mesh of silk, mono- or multifilaments made of synthetic fibers such as for example polyamides or polyesters or metal threads stretched tightly on a frame made for example of wood or a metal (e.g. aluminum or stainless steel). Alternatively, the screen-printing mesh may be a chemically etched, a laser-etched, or a galvanically formed porous metal foil, e.g. a stainless steel foil. The pores of the mesh are blocked in the non-image areas and left open in the image area, the image carrier being called the screen. Screen printing might be of the flat-bed or rotary type. Screen printing is further described for example in The Printing ink manual, R.H. Leach and R.J. Pierce, Springer Edition, 5th Edition, pages 58-62 and in Printing Technology, J.M. Adams and P.A. Dolin, Delmar Thomson Learning, 5th Edition, pages 293-328.

[0042] Rotogravure (also referred in the art as gravure) is a printing process wherein the image elements are engraved into the surface of a cylinder. The non-image areas are at a constant original level. Prior to printing, the entire printing

plate (non-printing and printing elements) is inked and flooded with ink. Ink is removed from the non-image by a wiper or a blade before printing, so that ink remains only in the cells. The image is transferred from the cells to the substrate by a pressure typically in the range of 2 to 4 bars and by the adhesive forces between the substrate and the ink. The term rotogravure does not encompass intaglio printing processes (also referred in the art as engraved steel die or copper plate printing processes) which rely for example on a different type of ink. More details are provided in "Handbook of print media", Helmut Kipphan, Springer Edition, page 48 and in The Printing ink manual, R.H. Leach and R.J. Pierce, Springer Edition, 5th Edition, pages 42-51.

[0043] Flexography preferably uses a unit with a doctor blade, preferably a chambered doctor blade, an anilox roller and plate cylinder. The anilox roller advantageously has small cells whose volume and/or density determines the ink application rate. The doctor blade lies against the anilox roller, and scraps off surplus ink at the same time. The anilox roller transfers the ink to the plate cylinder which finally transfers the ink to the substrate. Specific design might be achieved using a designed photopolymer plate. Plate cylinders can be made from polymeric or elastomeric materials. Polymers are mainly used as photopolymer in plates and sometimes as a seamless coating on a sleeve. Photopolymer plates are made from light-sensitive polymers that are hardened by ultraviolet (UV) light. Photopolymer plates are cut to the required size and placed in an UV light exposure unit. One side of the plate is completely exposed to UV light to harden or cure the base of the plate. The plate is then turned over, a negative of the job is mounted over the uncured side and the plate is further exposed to UV light. This hardens the plate in the image areas. The plate is then processed to remove the unhardened photopolymer from the nonimage areas, which lowers the plate surface in these nonimage areas. After processing, the plate is dried and given a post-exposure dose of UV light to cure the whole plate. Preparation of plate cylinders for flexography is described in Printing Technology, J. M. Adams and P.A. Dolin, Delmar Thomson Learning, 5th Edition, pages 359-360 and in The Printing ink manual, R.H. Leach and R.J. Pierce, Springer Edition, 5th Edition, pages 33-42.

[0044] The first and second radiation curable coating compositions are independently applied during steps a') and a'') thus forming the first coating layer (x20') and the second coating layer (x20''), respectively. The first and second radiation curable coating compositions independently comprise a binder and the platelet-shaped magnetic or magnetizable pigment particles described herein. The first radiation curable coating composition is applied during step a') on the substrate (x10) thus forming the first coating layer (x20') and the second radiation curable coating composition may be applied either on the same side (see Figs 7A and 8A) as the first coating layer (x20') or on the opposite side, i.e. the side of the substrate (x10) lacking the first coating layer (x20') (see Figs 7B and 8B) in register during step a'') thus forming the second coating layer (x20'').

[0045] According to one embodiment, the first radiation curable coating composition exhibits a color and the second radiation curable coating composition exhibits the same color with the naked eyes. According to one embodiment, the first and second radiation curable coating compositions have different binders but comprise the same platelet-shaped magnetic or magnetizable pigment particles so that they exhibit the same color with the naked eyes. According to another embodiment, the first and second radiation curable coating compositions are the same, i.e. they comprise the same binder and comprise the same platelet-shaped magnetic or magnetizable pigment particles. According to one embodiment wherein the OEL comprises a third motif, the first radiation curable coating composition exhibits a color, the second radiation curable coating composition exhibits the same color with the naked eyes and the third radiation curable coating composition exhibits the same color with the naked eyes as the first and the second compositions with the naked eyes.

[0046] According to one embodiment, the first radiation curable coating composition exhibits a first color and the second radiation curable coating composition exhibits a second color, said second color being different from the first color as observed with the naked eyes. According to one embodiment, the first and second radiation curable coating compositions have a same binder but comprise different platelet-shaped magnetic or magnetizable pigment particles so that they exhibit a different color with the naked eyes. According to said embodiment, the so-obtained OEL not only exhibit an eye catching effect due to its dynamic and highly bright effect but also a high level of counterfeit resistance due to the sophisticated adjacent motifs of different colors.

[0047] According to one embodiment, the first and second radiation curable coating compositions comprise the same platelet-shaped magnetic or magnetizable pigment particles but comprise a different binder, the binder of the first composition comprising a dye and/or a colorant so that the compositions exhibit a different color with the naked eyes. According to one embodiment, the first and second radiation curable coating compositions comprise the same platelet-shaped magnetic or magnetizable pigment particles but comprise a different binder, the binder of the second composition comprising a dye and/or a colorant so that the compositions exhibit a different color with the naked eyes. According to one embodiment, the first and second radiation curable coating compositions comprise the same platelet-shaped magnetic or magnetizable pigment particles but comprise a different binder, the binder of the first composition comprising a dye and/or colorant and the binder of the second composition comprising a dye and/or a colorant having a different color so that the compositions exhibit a different color with the naked eyes. For optically variable platelet-shaped magnetic or magnetizable pigment particles, i.e. pigments exhibiting a different color upon tilting (i.e. exhibiting a face color and a different angle color), "different colors" refer to different face colors or different angle colors or different face and angle

colors. According to one embodiment, the first radiation curable coating composition comprises optically variable platelet-shaped magnetic or magnetizable pigment particles having a first face color and a first angle color and the second radiation curable coating composition comprises optically variable platelet-shaped magnetic or magnetizable pigment particles having a second face color and a second angle color, wherein the first face color is different from the second face color and the first angle color is different from the second angle color. According to one embodiment, the first radiation curable coating composition comprises optically variable platelet-shaped magnetic or magnetizable pigment particles having a first face color and a first angle color and the second radiation curable coating composition comprises optically variable platelet-shaped magnetic or magnetizable pigment particles having a second face color and a second angle color, wherein the first face color is the same as the second face color and the first angle color is different from the second angle color. According to one embodiment, the first radiation curable coating composition comprises optically variable platelet-shaped magnetic or magnetizable pigment particles having a first face color and a first angle color and the second radiation curable coating composition comprises optically variable platelet-shaped magnetic or magnetizable pigment particles having a second face color and a second angle color, wherein the first face color is different from the second face color and the first angle color is the same as the second angle color.

[0048] According to one embodiment wherein the OEL comprises a third motif, the first radiation curable coating composition exhibits a color, the second radiation curable coating composition exhibits the same color with the naked eyes and the third radiation curable coating composition exhibits a different color with the naked eyes; or the first radiation curable coating composition exhibits a color, the third radiation curable coating composition exhibits the same color with the naked eyes and the second radiation curable coating composition exhibits a different color with the naked eyes; or the second radiation curable coating composition exhibits a color, the third radiation curable coating composition exhibits the same color with the naked eyes and the first radiation curable coating composition exhibits a different color with the naked eyes. According to one embodiment wherein the OEL comprises a third motif, the first radiation curable coating composition exhibits a color, the second radiation curable coating composition exhibits a different color with the naked eyes and the third radiation curable coating composition exhibits a different color with the naked eyes (or in other words the first, second and third compositions have different colors).

[0049] The first and second coating compositions described herein as well as the first coating layer (x20') and the second coating layer (x20") described herein comprise the platelet-shaped magnetic or magnetizable pigment particles described herein. In contrast to needle-shaped pigment particles which can be considered as quasi one-dimensional particles, platelet-shaped pigment particles are quasi two-dimensional particles due to the large aspect ratio of their dimensions. As shown in Fig. 2, platelet-shaped pigment particle can be considered as a two-dimensional structure wherein the dimensions X and Y are substantially larger than the dimension Z. Platelet-shaped pigment particles are also referred in the art as oblate particles or flakes. Such pigment particles may be described with a main axis X corresponding to their longest dimension crossing the pigment particle and a second axis Y perpendicular to X and corresponding to the second longest dimension crossing the pigment particle. In other words, the XY plane roughly defines the plane formed by the first and second longest dimensions of the pigment particle, the Z dimension being ignored.

[0050] The platelet-shaped magnetic or magnetizable pigment particles described herein have, due to their non-spherical shape, non-isotropic reflectivity with respect to incident electromagnetic radiation for which the hardened/cured binder material is at least partially transparent. As used herein, the term "non-isotropic reflectivity" denotes that the proportion of incident radiation from a first angle that is reflected by a particle into a certain (viewing) direction (a second angle) is a function of the orientation of the particles, i.e. that a change of the orientation of the particle with respect to the first angle can lead to a different magnitude of the reflection to the viewing direction.

[0051] In the first and second motifs of the OELs described herein, the platelet-shaped magnetic or magnetizable pigment particles described herein are dispersed in the first and second coating layers (x20' and x20"), respectively, said layers independently comprising a hardened binder material that fixes the orientation of the platelet-shaped magnetic or magnetizable pigment particles. The binder material is at least in its hardened or solid state (also referred to as second state herein), at least partially transparent to electromagnetic radiation of a range of wavelengths comprised between 200 nm and 2500 nm, i.e. within the wavelength range which is typically referred to as the "optical spectrum" and which comprises infrared, visible and UV portions of the electromagnetic spectrum. Accordingly, the particles contained in the binder material in its hardened or solid state and their orientation-dependent reflectivity can be perceived through the binder material at some wavelengths within this range. Preferably, the hardened binder material is at least partially transparent to electromagnetic radiation of a range of wavelengths comprised between 200 nm and 800 nm, more preferably comprised between 400 nm and 700 nm. Herein, the term "transparent" denotes that the transmission of electromagnetic radiation through a layer of 20 μm of the hardened binder material as present in the OEL (not including the platelet-shaped magnetic or magnetizable pigment particles, but all other optional components of the OEL in case such components are present) is at least 50%, more preferably at least 60 %, even more preferably at least 70%, at the wavelength(s) concerned. This can be determined for example by measuring the transmittance of a test piece of the hardened binder material (not including the platelet-shaped magnetic or magnetizable pigment particles) in accordance with well-established test methods, e.g. DIN 5036-3 (1979-11).

[0052] The platelet-shaped magnetic or magnetizable pigment particles described herein are defined as having, due to their non-spherical shape, non-isotropic reflectivity with respect to an incident electromagnetic radiation for which the cured binder material is at least partially transparent. As used herein, the term "non-isotropic reflectivity" denotes that the proportion of incident radiation from a first angle that is reflected by a particle into a certain (viewing) direction (a second angle) is a function of the orientation of the particles, i.e. that a change of the orientation of the particle with respect to the first angle can lead to a different magnitude of the reflection to the viewing direction. Preferably, the platelet-shaped magnetic or magnetizable pigment particles described herein have a non-isotropic reflectivity with respect to incident electromagnetic radiation in some parts or in the complete wavelength range of from about 200 to about 2500 nm, more preferably from about 400 to about 700 nm, such that a change of the particle's orientation results in a change of reflection by that particle into a certain direction. As known by the man skilled in the art, the magnetic or magnetizable pigment particles described herein are different from conventional pigments, in that said conventional pigment particles exhibit the same color and reflectivity, independent of the particle orientation, whereas the magnetic or magnetizable pigment particles described herein exhibit either a reflection or a color, or both, that depend on the particle orientation.

[0053] The first and second radiation curable coating compositions described herein as well as the first and second coating layers (x20', x20") described herein independently comprise the platelet-shaped magnetic or magnetizable pigment particles described herein preferably in an amount from about 1 wt.% and about 40 wt.%, preferably between about 3 wt.% and about 35 wt.%, more preferably between about 5 wt.% and about 30 wt.%, the weight percentages being based on the total weight of the radiation curable coating composition or the coating layer.

[0054] Suitable examples of platelet-shaped magnetic or magnetizable pigment particles described herein include without limitation pigment particles comprising a magnetic metal selected from the group consisting of cobalt (Co), iron (Fe), and nickel (Ni); a magnetic alloy of iron, manganese, cobalt, nickel or a mixture of two or more thereof; a magnetic oxide of chromium, manganese, cobalt, iron, nickel or a mixture of two or more thereof; or a mixture of two or more thereof. The term "magnetic" in reference to the metals, alloys and oxides is directed to ferromagnetic or ferrimagnetic metals, alloys and oxides. Magnetic oxides of chromium, manganese, cobalt, iron, nickel or a mixture of two or more thereof may be pure or mixed oxides. Examples of magnetic oxides include without limitation iron oxides such as hematite (Fe_2O_3), magnetite (Fe_3O_4), chromium dioxide (CrO_2), magnetic ferrites (MFe_2O_4), magnetic spinels (MR_2O_4), magnetic hexaferrites ($\text{MFe}_{12}\text{O}_{19}$), magnetic orthoferrites (RFeO_3), magnetic garnets $\text{M}_3\text{R}_2(\text{AO}_4)_3$, wherein M stands for two-valent metal, R stands for three-valent metal, and A stands for four-valent metal.

[0055] Examples of platelet-shaped magnetic or magnetizable pigment particles described herein include without limitation pigment particles comprising a magnetic layer M made from one or more of a magnetic metal such as cobalt (Co), iron (Fe), or nickel (Ni); and a magnetic alloy of iron, cobalt or nickel, wherein said magnetic or magnetizable pigment particles may be multilayered structures comprising one or more additional layers. Preferably, the one or more additional layers are layers A independently made from one or more selected from the group consisting of metal fluorides such as magnesium fluoride (MgF_2), silicon oxide (SiO), silicon dioxide (SiO_2), titanium oxide (TiO_2), and aluminum oxide (Al_2O_3), more preferably silicon dioxide (SiO_2); or layers B independently made from one or more selected from the group consisting of metals and metal alloys, preferably selected from the group consisting of reflective metals and reflective metal alloys, and more preferably selected from the group consisting of silver (Ag), aluminum (Al), chromium (Cr), and nickel (Ni), and still more preferably aluminum (Al); or a combination of one or more layers A such as those described hereabove and one or more layers B such as those described hereabove. Typical examples of the platelet-shaped magnetic or magnetizable pigment particles being multilayered structures described hereabove include without limitation A/M multilayer structures, A/M/A multilayer structures, A/M/B multilayer structures, A/B/M/A multilayer structures, A/B/M/B multilayer structures, A/B/M/B/A multilayer structures, B/M multilayer structures, B/M/B multilayer structures, M/A/M multilayer structures, B/A/M/A multilayer structures, B/A/M/B multilayer structures, B/A/M/B/A multilayer structures, B/A/M/A/B multilayer structures, B/A/B/A/M/A/B/A/B multilayer structures, A/B/A/B/A/M/A/B/A/B/A multilayer structures, wherein the layers A, the magnetic layers M and the layers B are chosen from those described hereabove.

[0056] The UV-Vis radiation curable coating composition described herein may comprise platelet-shaped optically variable magnetic or magnetizable pigment particles, and/or platelet-shaped magnetic or magnetizable pigment particles having no optically variable properties. Preferably, at least a part of the platelet-shaped magnetic or magnetizable pigment particles described herein is constituted by platelet-shaped optically variable magnetic or magnetizable pigment particles. In addition to the overt security provided by the colorshifting property of the optically variable magnetic or magnetizable pigment particles, which allows easily detecting, recognizing and/or discriminating an article or security document carrying an ink, coating composition, or coating layer comprising the optically variable magnetic or magnetizable pigment particles described herein from their possible counterfeits using the unaided human senses, the optical properties of the optically variable magnetic or magnetizable pigment particles may also be used as a machine readable tool for the recognition of the OEL. Thus, the optical properties of the optically variable magnetic or magnetizable pigment particles may simultaneously be used as a covert or semi-covert security feature in an authentication process wherein the optical (e.g. spectral) properties of the pigment particles are analyzed and thus increase the counterfeiting resistance.

[0057] The use of platelet-shaped optically variable magnetic or magnetizable pigment particles in coating layers for

producing an OEL enhances the significance of the OEL as a security feature in security document applications, because such materials are reserved to the security document printing industry and are not commercially available to the public.

[0058] As mentioned above, preferably at least a part of the platelet-shaped magnetic or magnetizable pigment particles is constituted by platelet-shaped optically variable magnetic or magnetizable pigment particles. These are more preferably selected from the group consisting of platelet-shaped magnetic thin-film interference pigment particles, platelet-shaped interference coated pigment particles.

[0059] Magnetic thin film interference pigment particles are known to those skilled in the art and are disclosed e.g. in US 4,838,648; WO 2002/073250 A2; EP 0 686 675 B1; WO 2003/000801 A2; US 6,838,166; WO 2007/131833 A1; EP 2 402 401 B1; WO 2019/103937 A1; EP 3 587 500 A1, EP 3 587 501 A1, EP 3 587 502 A1, EP 3 587 503 A1, WO 2020/006286 A1, WO 2020/131700 A1, US 2021/0101402, US 2021/038812, US 2022/0282094, and in the documents cited therein. Preferably, the magnetic thin film interference pigment particles comprise pigment particles having a five-layer Fabry-Perot multilayer structure and/or pigment particles having a six-layer Fabry-Perot multilayer structure and/or pigment particles having a seven-layer Fabry-Perot multilayer structure and/or pigment particles having a nine-layer Fabry-Perot multilayer structure and/or pigment particles having an eleven-layer Fabry-Perot multilayer structure and/or pigment particles having a multilayer structure combining one or more multilayer Fabry-Perot structures.

[0060] Preferred five-layer Fabry-Perot multilayer structures consist of absorber/dielectric/reflector/dielectric/absorber multilayer structures wherein the reflector and/or the absorber is also a magnetic layer, preferably the reflector and/or the absorber is a magnetic layer comprising nickel, iron and/or cobalt, and/or a magnetic alloy comprising nickel, iron and/or cobalt and/or a magnetic oxide comprising nickel (Ni), iron (Fe) and/or cobalt (Co).

[0061] Further preferred five-layer Fabry-Perot multilayer structures consist of dielectric/reflector/magnetic/reflector/dielectric multilayer structures.

[0062] Preferred six-layer Fabry-Perot multilayer structures consist of absorber/dielectric/reflector/magnetic/dielectric/absorber multilayer structures.

[0063] Preferred seven-layer Fabry Perot multilayer structures consist of absorber/dielectric/reflector/magnetic/reflector/dielectric/absorber multilayer structures such as disclosed in US 4,838,648.

[0064] Preferred nine-layer Fabry-Perot multilayer structures consist of dielectric/absorber/dielectric/reflector/magnetic/dielectric/absorber/dielectric multilayer structures.

[0065] Preferred eleven-layer Fabry-Perot multilayer structures consist of absorber/dielectric/absorber/dielectric/reflector/magnetic/reflector/dielectric/absorber/dielectric/absorber multilayer structures.

[0066] Preferably, the reflector layers described herein are independently made from one or more selected from the group consisting of metals and metal alloys, preferably selected from the group consisting of reflective metals and reflective metal alloys, more preferably selected from the group consisting of aluminum (Al), silver (Ag), copper (Cu), gold (Au), platinum (Pt), tin (Sn), titanium (Ti), palladium (Pd), rhodium (Rh), niobium (Nb), chromium (Cr), nickel (Ni), and alloys thereof, even more preferably selected from the group consisting of aluminum (Al), chromium (Cr), nickel (Ni) and alloys thereof, and still more preferably aluminum (Al). Preferably, the dielectric layers are independently made from one or more selected from the group consisting of metal fluorides such as magnesium fluoride (MgF_2), aluminum fluoride (AlF_3), cerium fluoride (CeF_3), lanthanum fluoride (LaF_3), sodium aluminum fluorides (e.g. Na_3AlF_6), neodymium fluoride (NdF_3), samarium fluoride (SmF_3), barium fluoride (BaF_2), calcium fluoride (CaF_2), lithium fluoride (LiF), and metal oxides such as silicon oxide (SiO), silicon dioxide (SiO_2), titanium oxide (TiO_2), aluminum oxide (Al_2O_3), more preferably selected from the group consisting of magnesium fluoride (MgF_2) and silicon dioxide (SiO_2) and still more preferably magnesium fluoride (MgF_2). Preferably, the absorber layers are independently made from one or more selected from the group consisting of aluminum (Al), silver (Ag), copper (Cu), palladium (Pd), platinum (Pt), titanium (Ti), vanadium (V), iron (Fe) tin (Sn), tungsten (W), molybdenum (Mo), rhodium (Rh), Niobium (Nb), chromium (Cr), nickel (Ni), metal oxides thereof, metal sulfides thereof, metal carbides thereof, and metal alloys thereof, more preferably selected from the group consisting of chromium (Cr), nickel (Ni), metal oxides thereof, and metal alloys thereof, and still more preferably selected from the group consisting of chromium (Cr), nickel (Ni), and metal alloys thereof. Preferably, the magnetic layer comprises nickel (Ni), iron (Fe) and/or cobalt (Co); and/or a magnetic alloy comprising nickel (Ni), iron (Fe) and/or cobalt (Co); and/or a magnetic oxide comprising nickel (Ni), iron (Fe) and/or cobalt (Co). When magnetic thin film interference pigment particles comprising a seven-layer Fabry-Perot structure are preferred, it is particularly preferred that the magnetic thin film interference pigment particles comprise a seven-layer Fabry-Perot absorber/dielectric/reflector/magnetic/reflector/dielectric/absorber multilayer structure consisting of a $\text{Cr/MgF}_2/\text{Al/M/Al/MgF}_2/\text{Cr}$ multilayer structure wherein M is Ni, Fe or Co.

[0067] The magnetic thin film interference pigment particles described herein may be multilayer pigment particles being considered as safe for human health and the environment and being based for example on five-layer Fabry-Perot multilayer structures, six-layer Fabry-Perot multilayer structures, seven-layer Fabry-Perot multilayer structures, nine-layer Fabry-Perot multilayer structures, eleven-layer Fabry-Perot multilayer structures and pigment particles having a multilayer structure combining one or more, or two or more, multilayer Fabry-Perot structures, wherein said pigment particles include one or more magnetic layers comprising a magnetic alloy having a substantially nickel-free composition

including about 40 wt.% to about 90 wt.% iron, about 10 wt.% to about 50 wt.% chromium and about 0 wt.% to about 30 wt.% aluminum. Typical examples of multilayer pigment particles being considered as safe for human health and the environment can be found in EP 2 402 401 B1 whose content is hereby incorporated by reference in its entirety.

[0068] Suitable interference coated pigment particles comprising one or more magnetic materials include without limitation structures consisting of a substrate selected from the group consisting of a core coated with one or more layers, wherein at least one of the core or the one or more layers have magnetic properties. For example, suitable interference coated pigment particles comprise a core made of a magnetic material such as those described hereabove, said core being coated with one or more layers made of one or more metal oxides, or they have a structure consisting of a core made of synthetic or natural micas, layered silicates (e.g. talc, kaolin and sericite), glasses (e.g. borosilicates), silicon dioxides (SiO_2), aluminum oxides (Al_2O_3), titanium oxides (TiO_2), graphites and mixtures of two or more thereof, said core being coated with one or more magnetic materials. Furthermore, one or more additional layers such as coloring layers may be present.

[0069] The platelet-shaped magnetic or magnetizable pigment particles of the first and second described herein preferably have a size d_{50} between about 2 μm and about 50 μm (as measured by direct optical granulometry).

[0070] The platelet-shaped magnetic or magnetizable pigment particles described herein may be surface treated so as to protect them against any deterioration that may occur in the coating composition and coating layer and/or to facilitate their incorporation in said coating composition and coating layer; typically corrosion inhibitor materials and/or wetting agents may be used.

[0071] Further, subsequently to the independent applications of the first and second radiation curable coating compositions described herein so as to form the first coating layer (x_{20}') and the second coating layer (x_{20}'') (step a') and step a'') described herein, said first and second radiation curable coating compositions of step a') and step a'') are independently exposed to the magnetic field of a magnetic assembly (x_{30}' , x_{30}'' , respectively) so as to independently magnetically orient at least a part of the platelet-shaped magnetic or magnetizable pigment particles (step b') and step b''), respectively).

[0072] The process described herein comprises at least two independent steps b') and b'') consisting of exposing the first and second radiation curable coating compositions described herein to the magnetic field of magnetic assemblies so as to magnetically orient at least a part of the platelet-shaped magnetic or magnetizable pigment particles, wherein the step b'') is carried out by exposing the second radiation curable coating composition of step a'') to the magnetic field of a magnetic assembly (x_{30}'') so as to bi-axially orient said pigment particles.

[0073] During the orientation step b') and step b'') described herein, the substrate (x_{10}) may be independently disposed on a non-magnetic supporting plate (x_{70}) which is made of one or more non-magnetic materials.

[0074] As described hereafter, " x_{30}' " and " x_{30}'' " independently either refer to single magnets or refer to assemblies (x_{30}) comprising two or more magnets or refer to assemblies comprising one or more magnets and an engraved magnetic plate, or refer to assemblies comprising one or more magnets and a soft magnetic plate or refers to an assembly comprising a magnet and one or more pole pieces or comprising two or more magnets and one or more pole pieces, said magnetic assemblies (x_{30}' and x_{30}'') being selected according to the design of the orientation patterns of the first and second motifs of the OELs to be produced. Should the magnetic assemblies (x_{30}' and x_{30}'') comprise more than one components, the platelet-shaped magnetic or magnetizable pigment particles are exposed to the resultant magnetic field of said more than one components.

[0075] The process described herein comprises the orientation step b') described herein.

[0076] According to one embodiment shown for example in Fig. 3A, the orientation step b') of the first set of steps (S1) is a one-step orientation step, wherein the substrate (310) carrying the first coating layer (320') obtained by screen printing (340') (step a')) is exposed to the magnetic field of a magnetic assembly (330') and wherein the first coating layer (320') is, partially simultaneously with step b'), at least partially cured with a first curing unit (350') (step c')).

[0077] According to one embodiment shown for example in Fig. 4A, the orientation step b') of the first set of steps (S1) is a one-step orientation step, wherein an assembly comprising the substrate (410) carrying the first coating layer (420') described herein is placed on a first magnetic assembly (430'-a) and said assembly is concomitantly moved in the vicinity of a static second magnetic assembly (430'-b).

[0078] According to one embodiment shown for example 4B, the process described herein allows the preparation of OELs, wherein step b') consists of placing the substrate (410) carrying the first coating layer (420') on a first magnetic assembly (430'-a) providing a first magnetic field vector component, said first magnetic assembly being mounted on a rotating magnetic cylinder thereby subjecting the platelet-shaped magnetic or magnetizable pigment particles to said first magnetic field vector component and concomitantly moving said substrate (410) carrying the first coating layer (420') and said first magnetic assembly (430'-a) in the vicinity of a static second magnetic assembly (430'-b), said second magnetic assembly (430'-b), providing a second magnetic field vector component, thereby subjecting the platelet-shaped magnetic or magnetizable pigment particles to a time-dependent resultant magnetic field formed by the first and second magnetic field vector components so as to bi-axially orient at least a part of the platelet-shaped magnetic or magnetizable pigment particle. According to one embodiment, the ratio of the magnetic flux density of the first magnetic assembly

(430'-a) and the magnetic flux density of the static second first magnetic assembly (430'-b) is less than about 4.0, preferably less than about 1.9 and more preferably between about 1.5 and about 0.5. The first magnetic assembly (430'-a) onto which the substrate (410) carrying the first coating layer (420') is preferably selected from the magnetic assemblies described hereabove for orienting pigment particles and the soft magnetic plates described hereabove. The second

magnetic assembly (430'-b) is preferably selected from the magnetic assemblies described hereabove for bi-axially orienting pigment particles. Such processes are disclosed in WO 2019/14142 A1 and WO 2019/141453 A1.

[0079] According to one embodiment shown for example in Fig. 5A, the orientation step b') of the first set of steps (S1) is a two-steps orientation step, said two-steps orientation step consisting of the two following ones: a first orienting step (b'-1) to bi-axially orient the platelet-shaped magnetic or magnetizable pigment particles such as described herein followed by a second orienting step to re-orient (b'-2) the platelet-shaped magnetic or magnetizable pigment particles such as described herein, wherein the substrate (510) carrying the first coating layer (520') is exposed to the magnetic field of a magnetic assembly (530'-a) and subsequently to the magnetic field of a magnetic assembly (530'-b), said both magnetic assemblies (530'-a and 530'-b) being positioned on the second side of the substrate (i.e. the side lacking the first coating layer (520')). Fig. 5B (not true to scale) illustrates a process wherein the orientation step b') consists of a

two-steps orientation step, wherein the first radiation curable coating composition described herein is first exposed to the magnetic field of a first magnetic assembly (530'-a) and subsequently exposed to the magnetic field of a second magnetic assembly (530'-b), wherein said second magnetic assembly (530'-b) is mounted on a rotating magnetic cylinder.

[0080] According to one embodiment shown for example in Fig. 6A-B, the orientation step b') of the first set of steps (S1) is a two-steps orientation step, said step two-steps consisting of the two following ones: a first orienting step (b'-1) to bi-axially orient the platelet-shaped magnetic or magnetizable pigment particles such as described herein followed by a second orienting step to re-orient (b'-2) the platelet-shaped magnetic or magnetizable pigment particles such as described herein, wherein the substrate (610) carrying the first coating layer (620') is exposed to the magnetic field of the magnetic assembly (630'-a) and subsequently to the resultant magnetic field of second magnetic assembly (630'-b) and of a third magnetic assembly (630'-c), said magnetic assemblies (630'-a, 630'-b, 630'-c) being positioned on the

side lacking the first coating layer (620').

[0081] Fig. 6B (not true to scale) illustrates a process wherein the orientation step b') of the first set of steps (S1) is a two-steps orientation step, said step two-steps consisting of the two following ones: a first orienting step (b'-1) to bi-axially orient the platelet-shaped magnetic or magnetizable pigment particles such as described herein followed by a second orienting step to re-orient (b'-2) the platelet-shaped magnetic or magnetizable pigment particles such as described herein, wherein the substrate (610) carrying the first coating layer (620') is exposed to the magnetic field of the magnetic assembly (630'-a) and subsequently to the resultant magnetic field of a second magnetic assembly (630'-b) and of a third magnetic assembly (630'-c), said magnetic assemblies 630'-a and 630'-b being positioned on the side lacking the first coating layer (620') and said magnetic assembly 630'-c being positioned on the side comprising the first coating layer (620'), wherein the magnetic assembly 630'-b is mounted on a rotating magnetic cylinder and the magnetic assembly 630'-c is placed outside the rotating magnetic cylinder. Suitable processes wherein the orientation steps b') consist of a two-steps orientation step are disclosed in WO 2015/086257 A1.

[0082] According to one embodiment, the process described herein allows the preparation of OELs wherein the first motif exhibits one or more indicia, wherein step b') consists of exposing the radiation curable coating composition to an engraved magnetic plate (x30), wherein said engraved magnetic plate (x30) comprises one or more engravings (I) having the shape of the one or more indicia. The engraved magnetic plate (x30) described herein is preferably made from a permanent magnetic powder material and a polymer. The engraved magnetic plate (x30) described herein may typically be produced by an injection molding process or by metal or laser engraving. Preferred permanent magnetic powder materials include cobalt, iron and their alloys, chromium dioxide, generic magnetic oxide spinels, generic magnetic garnets, generic magnetic ferrites including the hexaferrites such as calcium-, strontium-, and barium-hexaferrite (CaFe₁₂O₁₉, SrFe₁₂O₁₉, BaFe₁₂O₁₉, respectively), generic alnico alloys, generic samarium-cobalt (SmCo) alloys, and generic rare-earth-iron-boron alloys (such as NdFeB), as well as the permanent-magnetic chemical derivatives thereof (such as indicated by the term generic) and mixtures thereof. Plates made of a composite material comprising a polymer and a permanent magnetic powder are obtainable from many different sources, such as from Bomatec, Höri, CH, ARNOLD® Magnetic Technologies (Plastiform®) or from Materiali Magnetici, Albairate, Milano, IT (Plastoferrite).

[0083] According to one embodiment, the process described herein allows the preparation of OELs wherein a first motif exhibits a dynamic movement upon tilting said OEL and one or more indicia, wherein said step b') consists of exposing the radiation curable coating composition to a magnetic assembly (x30) comprising a bar dipole magnet and an engraved magnetic plate, wherein said engraved magnetic plate comprises one or more engravings having the shape of the one or more indicia, wherein the engraved magnetic plate is placed above the bar dipole magnet.

[0084] According to one embodiment, the process described herein comprises the step b') consisting of exposing the first radiation curable coating composition to a magnetic assembly such as those disclosed in US 8,025,952 and EP 1 819 525 B1 and WO 2022/049024 A1, wherein this effect is so-called Venetian-blind" effect. Fig. 5A-B of US 7,047,883 discloses a magnetic assembly comprising two spaced apart magnets 84 placed on a magnetic base 62 with their North

poles facing the substrate. Fig. 9B of US 7,047,883 discloses a magnetic assembly comprising a magnet 140 and the substrate comprising the coating layer being placed with an offset position relatively the magnet axes. Fig. 9C of US 7,047,883 discloses a magnetic assembly comprising two magnets 142 and one magnet 142' having a diamond-shaped cross section, wherein the two magnets 142 have their North pole facing the substrate while the intervening magnet 142' has its South pole facing the substrate. Fig. 9D of US 7,047,883 discloses a magnetic assembly comprising two magnets 144, and one magnet 144' having roof-shaped, hexagonal, rounded, trapezoidal, or other cross-sections, wherein the two magnets 144 have their North pole facing the substrate while the intervening magnet 144' has its South pole facing the substrate. Fig. 9E of US 7,047,883 discloses a magnetic assembly comprising five magnets, the first magnet 142 being a diamond-shaped magnet with its North pole facing the substrate, the second magnet 146 being a rectangular magnet with its South pole facing the substrate, the third magnet 148 being a magnet with rounded top having its North pole facing the substrate, the fourth magnet 150 being a roof-shaped and having its South pole facing the substrate and the fifth magnet 152 being also a roof-shaped magnet and having its North pole facing the substrate. Fig. 4A1 of WO 2022/049024 A1 discloses a magnetic assembly comprising a bar dipole magnet and the particles are exposed to the magnetic field (magnetic field lines shown as lines with arrows pointing from the North Pole to the South Pole) of the magnetic assembly in one or more areas (shown as a dotted rectangle A) wherein the magnetic field is substantially homogeneous and wherein the magnetic field lines are substantially parallel to each other in said one or more areas. Fig. 4A2 of WO 2022/049024 A1 discloses a magnetic assembly comprising two bar dipole magnets (M1, M2) having a same magnetic direction and an iron yoke (Y) and the particles are exposed to the magnetic field (magnetic field lines shown as lines with arrows pointing from the North Pole to the South Pole) of the magnetic assembly in one or more areas (shown as a dotted rectangle A) wherein the magnetic field is substantially homogeneous and wherein the magnetic field lines are substantially parallel to each other in said one or more areas. Fig. 6A-B of WO 2022/049024 A1 discloses a magnetic assembly comprising a rectangular assembly comprising two bar dipole magnets (M1, M2) and two pole pieces (P1, P2) and the particles are exposed to the magnetic field (magnetic field lines shown as lines with arrows pointing from the North Pole to the South Pole) of the magnetic assembly in one or more areas (shown as a dotted rectangle A) wherein the magnetic field is substantially homogeneous and wherein the magnetic field lines are substantially parallel to each other in said area.

[0085] According to one embodiment shown for example in Fig. 11 (examples E1-E5, magnetic assembly (1130) used during step b'), the process described herein allows the preparation of OELs wherein the first motif exhibits a dynamic motion upon tilting said OEL, said dynamic movement being a bright reflective horizontal bar moving in a vertical direction (up/down) when the OEL is tilted around a horizontal axis; wherein said step b') consists of exposing the first radiation curable coating composition to a bar dipole magnet having a magnetic axis oriented to be substantially parallel to a substrate and substantially parallel to the machine feed direction. This effect is the so-called "rolling bar" effect, as disclosed in US 2005/0106367. A "rolling bar" effect is based on pigment particles orientation imitating a curved surface across the coating. The observer sees a specular reflection zone/bar which moves away or towards the observer as the OEL is tilted.

[0086] According to another embodiment, the process described herein allows the preparation of OELs wherein the first motif exhibits a dynamic motion upon tilting said OEL, said dynamic movement of the OEL being a bright reflective vertical bar moving in a horizontal (left/right) direction when the OEL is tilted around a vertical axis; wherein said step b') consists of exposing the first radiation curable coating composition to a bar dipole magnet having a magnetic axis oriented to be substantially parallel to the substrate and substantially perpendicular to the machine feed direction. This effect is the so-called "rolling bar" effect, as disclosed in US 2005/0106367.

[0087] According to another embodiment, the process described herein allows the preparation of OELs wherein the first motif exhibits a dynamic motion upon tilting said OEL, said dynamic movement of the OEL being a bright reflective vertical bar moving in a horizontal (left/right) direction when the OEL is tilted around a horizontal axis; wherein said step b') consists of exposing the first radiation curable coating composition to a magnetic assembly such as those disclosed in WO 2020/160993 A1. Figs 2-5 of WO 2020/160993 A1 discloses magnetic assemblies comprising a) at least one dipole magnet (x40) being a square-shaped or rectangle-shaped dipole magnet having its magnetic axis oriented to be substantially parallel to a substrate and b) a combination of n sets of spaced apart bar dipole magnets (x30-a1, x30-a2) with n being an integer equal to or bigger than 1, wherein each of said bar dipole magnets (x30-a1, x30-a2) has its North-South magnetic axis substantially parallel to the substrate surface, wherein, for each set of said n sets, the bar dipole magnets (x30-a1, x30-a2) have their North pole pointing in a same direction and are substantially parallel to each other; wherein the vector sum H1 of the magnetic axes of the bar dipole magnets (x30-a1, x30-a2) and the vector sum H2 of the at least one dipole magnet (x40) form an angle α in the range from about 5° to about 175° or in the range from about 185° to about 355°; wherein the combination of n sets of spaced apart bar dipole magnets (x30-a1, x30-a2) is placed below or above the at least one dipole magnet (x40), and wherein the at least one dipole magnet (x40) and the combination of n sets of spaced apart bar dipole magnets (x30-b1, x30-b2) are essentially centered with respect to one another (see for example Figs 2-5 of WO 2020/160993 A1).

[0088] According to another embodiment, the process described herein allows the preparation of OELs wherein the

first motif exhibits a dynamic motion upon tilting said OEL, said dynamic movement of the OEL a bright reflective horizontal bar moving in a vertical direction (up/down) when the OEL is tilted around a horizontal axis; wherein said step b') consists of exposing the first radiation curable coating composition to a magnetic assembly such as those disclosed in WO 2014/198905 A2. Figs 5-9 of WO 2014/198905 A2 disclose magnetic assemblies comprising:

- a) a bar dipole magnet (M1) and a pair of bar dipole magnets (M2) and (M3), said bar dipole magnets (M1), (M2) and (M3) having their North-South axis substantially parallel to the substrate and the same magnetic North-South direction, wherein a1) said bar dipole magnet (M1) is disposed below the substrate and said pair of bar dipole magnets (M2) and (M3) are disposed below the bar dipole magnet (M1) apart from each other; or a2) said pair of bar dipole magnets (M2) and (M3) are disposed below the substrate and apart from each other, and said bar dipole magnet (M1) is disposed below said pair of bar dipole magnets (M2) and (M3); or
- b) a pair of bar dipole magnets (M4) and (M5) and a pole piece (Y), said pair of bar dipole magnets (M4) and (M5) having their North-South axis substantially parallel to the substrate and the same magnetic North-South direction, said pole piece (Y) being disposed between said bar dipole magnet (M4) and said bar dipole magnet (M5); or
- c) a pair of bar dipole magnets (M4) and (M5), a pole piece (Y) and a magnetic plate (M6), said pair of bar dipole magnets (M4) and (M5) having their North-South axis substantially parallel to the substrate and the same magnetic North-South direction, said magnetic plate (M6) having its North-South axis substantially perpendicular to the substrate, said pole piece (Y) being disposed between said bar dipole magnet (M4) and said bar dipole magnet (M5). Particularly suitable magnetic assemblies are those shown in Figs 5c, 6c and 7d of WO 2014/198905 A2.

[0089] According to one embodiment, the process described herein allows the preparation of OELs wherein at least one of the first motif and second motif exhibits a dynamic motion upon tilting said OEL, said dynamic movement being a pattern of bright areas and dark areas moving when the OEL is tilted; wherein said steps b') consists of exposing the radiation curable coating composition to a magnetic assembly such as those disclosed in WO 2013/167425 A1 and WO 2021/083809 A1. Disclosed magnetic assemblies of WO 2021/083809 A1 comprise at least one dipole magnet (x41) having a magnetic axis oriented to be substantially parallel to the substrate and a combination comprising at least four additional dipole magnets (x31) having their North poles pointing in a same direction and having their magnetic axes oriented to be substantially parallel to the substrate, wherein each of the additional dipole magnets (x31) is arranged on an intersection of at least two substantially parallel straight lines α_i ($i = 1, 2, \dots$) and at least two substantially parallel straight lines β_j ($j = 1, 2, \dots$), the straight lines α_i and β_j forming a grid, wherein at least two additional dipole magnets (x31) are disposed on one of the straight lines α_i and at least two other additional dipole magnets (x31) are disposed on another one of the straight lines α_i , wherein the magnetic axes of the additional dipole magnets are oriented substantially parallel to the substantially parallel straight lines α_i , wherein the at least one dipole magnet (x40) is disposed below the combination comprising at least four dipole magnets (x31). According to one embodiment, each straight line α_i and a vector H of the magnetic axis of the at least one dipole magnet (x41) is substantially parallel or substantially perpendicular with respect to each other and the OEL exhibits a dynamic movement being a pattern of bright areas and dark areas moving when the substrate carrying said OEL is tilted, said pattern of bright areas and dark areas moving in the same direction as the tilting direction. According to another embodiment, each straight line α_i and a vector H of the magnetic axis of the at least one dipole magnet (x41) is substantially non-parallel and substantially non-perpendicular with respect to each other OEL, preferably wherein each straight line α_i and the vector sum H of the magnetic axis of the at least one dipole magnet (x41) form an angle γ in the range from about 20° to about 70° or in the range from about 110° to about 160° or in the range from about 200° to about 250°, or in the range from about 290° to about 340°; and the OEL exhibits a dynamic movement being a pattern of bright areas and dark areas moving not only in a diagonal direction when the substrate carrying said OEL is tilted around a vertical axis but also moving in a diagonal direction when the substrate carrying said OEL is tilted around a horizontal axis (in other words, the optical effect layer OEL described herein provides the optical impression of a plurality of dark and a plurality of bright spots that are moving when the substrate carrying said OEL is tilted around two perpendicular axes, i.e. horizontal axis and vertical axis. Suitable magnetic assemblies are those shown in Figs 6-8 of WO 2021/083809 A1.

[0090] According to one embodiment, the process described herein allows the preparation of OELs wherein at least one of the first motif and second motif exhibits a dynamic motion upon tilting said OEL, said dynamic movement being a pattern of bright areas and dark areas moving when the OEL is tilted; wherein said steps b') consists of exposing the radiation curable coating composition to a magnetic assembly such as those disclosed in WO 2021/083808 A1. Disclosed magnetic assemblies of WO 2021/083808 A1 comprise at least one dipole magnet (x41) having a magnetic axis oriented to be substantially parallel to the substrate and a combination comprising at least four additional dipole magnets (x31) having their North poles pointing in a same direction and having their magnetic axes oriented to be substantially parallel to the substrate, wherein each of the additional dipole magnets (x31) is arranged on an intersection of at least two substantially parallel straight lines α_i ($i = 1, 2, \dots$) and at least two substantially parallel straight lines β_j ($j = 1, 2, \dots$), the straight lines α_i and β_j forming a grid, wherein at least two additional dipole magnets (x31) are disposed on one of the

straight lines α_i and at least two other additional dipole magnets (x31) are disposed on another one of the straight lines α_i , wherein the magnetic axes of the additional dipole magnets (x31) are oriented substantially parallel to the substrate, straight lines α_i , wherein the at least one dipole magnet (x41) is disposed below the combination comprising at least four first dipole magnets (x31), wherein, on each straight line α_i , and on each straight line β_j , neighboring additional dipole magnets (x31) have their North pole pointing in an opposite direction, wherein each straight line α_i and a vector H of the magnetic axis of the at least one dipole magnet (x41) is substantially non-parallel and substantially non-perpendicular with respect to each other OEL, preferably wherein each straight line α_i and the vector sum H of the magnetic axis of the at least one dipole magnet (x41) form an angle γ in the range from about 20° to about 70° or in the range from about 110° to about 160° or in the range from about 200° to about 250°, or in the range from about 290° to about 340°; and the OEL exhibits a dynamic movement being a pattern of bright areas and dark areas moving not only in a diagonal direction when the substrate carrying said OEL is tilted about a vertical axis but also moving in a diagonal direction when the substrate carrying said OEL is tilted about a horizontal axis (in other words, the optical effect layer OEL described herein provides the optical impression of a plurality of dark and a plurality of bright spots that are moving when the substrate carrying said OEL is tilted about two perpendicular axes, i.e. horizontal axis and vertical axis). Suitable magnetic assemblies are those shown in Figs 5-7 of WO 2021/083808 A1.

[0091] According to one embodiment, the process described herein allows the preparation of OELs wherein the first motif exhibits a dynamic motion upon tilting said OEL, said dynamic movement being a loop-shaped body moving when the OEL is tilted; wherein said step b') consists of exposing the first radiation curable coating composition to a magnetic assembly such as those disclosed in WO 2014/108404 A2. The disclosed magnetic assemblies of WO 2014/108404 A2 comprise either a) at least one dipole magnet having a magnetic axis oriented to be substantially perpendicular to the substrate and one or more pole pieces, said one or more pole pieces being disposed below the at least one dipole magnet and in contact with the dipole magnet and/or being spaced apart from and laterally surrounding the at least one dipole magnet (see for example Figs 3-5 of WO 2014/108404 A2); b) the at least one dipole magnet being a loop-shaped magnet having a radial magnetization (i.e. having its magnetic North-South axis radially extending from the center of the loop-shaped magnet to the periphery) (see for example Fig. 6 of WO 2014/108404 A2); or c) the at least one dipole magnet being three or more dipole magnets disposed in a loop-shaped arrangement having a radial magnetization (i.e. each of said three or more dipole magnets has its magnetic axis oriented to be substantially parallel to the substrate and has its magnetic axis aligned such as to be substantially radially extending from the center of symmetry of the loop-shaped arrangement, wherein the North-South directions of said three or more dipole magnets point either all towards or all away from the center of symmetry (see for example Fig. 7 of WO 2014/108404 A2). WO 2014/108404 A2 also disclose spinneable magnetic assemblies comprising a) at least two bar dipole magnets having their magnetic axis substantially parallel to the substrate and having either the same magnetic direction (Fig. 9) or an opposite magnetic direction (see Fig. 11 of WO 2014/108404 A2) or comprising b) at least two bar dipole magnets having their magnetic axis substantially perpendicular to the substrate and having an opposite magnetic direction (see Fig. 10 of WO 2014/108404 A2).

[0092] According to one embodiment, the process described herein allows the preparation of OELs wherein the first motif exhibits a dynamic motion upon tilting said OEL, said dynamic movement being a multi-loop-shaped body moving when the OEL is tilted; wherein said step b') consists of exposing the first radiation curable coating composition to a magnetic assembly such as those disclosed in WO 2014/108303 A2. Disclosed magnetic assemblies of WO 2014/108303 A2 comprise one of the following:

- a) at least one dipole magnet being a loop-shaped magnet defining a loop and having a magnetic axis oriented to be substantially perpendicular to the substrate and a pole piece (x60) being disposed below the at least one dipole magnet and within the loop of said at least one dipole magnet and having one or more protrusions disposed within the loop of the at least one dipole magnet (see for example Figs 3-5 of WO 2014/108303 A2); or
- b) at least one dipole magnet having a magnetic axis oriented to be substantially perpendicular to the substrate, an additional dipole magnet having a magnetic axis oriented to be substantially perpendicular to the substrate and two or more pole pieces, wherein said at least one dipole magnet and additional magnet have the same magnetic direction and are provided in different distances from substrate, wherein said two or more pole pieces are arranged in the space between the magnets and in contact therewith and wherein at least one of the two or more pole pieces form one or more loop-shaped projections surrounding a central area in which the at least one dipole magnet is arranged (see for example Fig. 6 WO of 2014/108303 A2); or
- c) at least one dipole magnet having a magnetic axis oriented to be substantially perpendicular to the substrate, a plate-like-shaped pole piece being disposed below and in contact with the at least one dipole magnet, and one or more loop-shaped pole pieces being disposed on top the at least one dipole magnet, wherein a central pole piece of said one or more loop-shaped pole pieces is in contact with the at least one dipole magnet, and wherein said plate-like-shaped pole piece may comprise one or more protrusions laterally and spaced apart surrounding the at least one dipole magnet (see for example Fig. 7 of WO 2014/108303 A2). WO 2014/108303 A2 also disclose

spinneable magnetic assemblies comprising a) at least two bar dipole magnets having their magnetic axis substantially perpendicular to the substrate (see Figs 8-10 and 13-14 of WO 2014/108303 A2) or comprising b) at least four bar dipole magnets having their magnetic axis substantially parallel to the substrate (see Figs 11, 12 and 15 of WO 2014/108303 A2).

[0093] According to one embodiment, the process described herein allows the preparation of OELs wherein the first motif exhibits a dynamic motion upon tilting said OEL, said dynamic movement being a loop-shaped body having a size that varies when the OEL is tilted; wherein said step b') consists of exposing the first radiation curable coating composition to a magnetic assembly such as those disclosed in WO 2017/064052 A1, WO 2017/080698 A1 and WO 2017/148789 A1. Disclosed magnetic assemblies of WO 2017/064052 A1, WO 2017/080698 A1 and WO 2017/148789 A1 comprise one of the following:

- a) at least one dipole magnet (x40) being either a single bar dipole magnet having a North-South magnetic axis substantially parallel to a substrate or a combination of two or more bar dipole magnets having a resulting North-South magnetic axis substantially parallel to the substrate and b) a loop-shaped magnetic-field generating device (x30) being either a single loop-shaped dipole magnet having a North-South magnetic axis substantially perpendicular to the substrate or a combination of two or more dipole magnets disposed in a loop-shaped arrangement and having a resulting North-South magnetic axis substantially perpendicular to the substrate (see for example Figs 1-4 of WO 2017/064052 A1), or
- a) at least one dipole magnet (x40) being either a single dipole magnet having a magnetic axis substantially parallel to the substrate or a combination of two or more bar dipole magnets, each of the two or more bar dipole magnets having a magnetic axis substantially parallel to the substrate and having a same magnetic field direction, b) a loop-shaped magnetic-field generating device (x31) being either a single loop-shaped dipole magnet having a magnetic axis substantially perpendicular to the substrate or a combination of two or more dipole magnets disposed in a loop-shaped arrangement, each of the two or more dipole magnets having a magnetic axis substantially perpendicular to the substrate and having a same magnetic field direction, and c) a single dipole magnet (x32) having a magnetic axis substantially perpendicular to the substrate or two or more dipole magnets, each of the two or more dipole magnets having a magnetic axis substantially perpendicular to the substrate and having a same magnetic field direction and/or one or more pole pieces (see for example Figs 1-12 of WO 2017/080698 A1), or
- a) at least one dipole magnet (x40) being either a single bar dipole magnet having a magnetic axis substantially parallel to the substrate or a combination of two or more bar dipole magnets, each of the two or more bar dipole magnets having a magnetic axis substantially parallel to the substrate and having a same magnetic field direction, b) a loop-shaped magnetic-field generating device (x31) being either a single loop-shaped magnet or a combination of two or more dipole magnets (x31), disposed in a loop-shaped arrangement, the loop-shaped magnetic-field generating device having a radial magnetization, and c) a single dipole magnet (x32) having a magnetic axis substantially perpendicular to the substrate or a single dipole magnet having a magnetic axis substantially parallel to the substrate (x32), or two or more dipole magnets (x32), each of said two or more dipole magnets (x32) having a magnetic axis substantially perpendicular to the substrate, wherein the North pole of said single dipole magnet (x32) or the North pole of at least one of said two or more dipole magnets (x32) is pointing towards the substrate when the North pole of the single loop-shaped magnet (x31) or of the two or more dipole magnets (x31) forming the loop-shaped magnetic-field generating device is pointing towards the periphery of said loop-shaped magnetic-field generating device, or wherein the South pole of said single dipole magnet (x32) or the South pole of at least one of said two or more dipole magnets (x32) is pointing towards the substrate when the South pole of the single loop-shaped magnet (x31) or of the two or more dipole magnets (x31) forming the loop-shaped magnetic-field generating device is pointing towards the periphery of said loop-shaped magnetic-field generating device (x31) (see for example Figs 1-14 of WO 2017/148789 A1).

[0094] According to one embodiment, the process described herein allows the preparation of OELs wherein the first motif exhibits a dynamic motion upon tilting said OEL, said dynamic movement being a loop-shaped body having a shape that varies when the OEL is tilted; wherein said step b') consists of exposing the first radiation curable coating composition to a magnetic assembly such as those disclosed in WO 2018/054819 A1. In particular, the disclosed magnetic assembly of WO 2018/054819 A1 comprises a loop-shaped magnetic-field generating device (x31) being either a single loop-shaped magnet (x31) or a combination of two or more dipole magnets (x31) disposed in a loop-shaped arrangement, the loop-shaped magnetic-field generating device (x31) having a radial magnetization; and a single dipole magnet (x32) having a magnetic axis substantially perpendicular to the substrate (x20) surface or two or more dipole magnets (x32), each of said two or more dipole magnets (x32) having a magnetic axis substantially perpendicular to the substrate surface, wherein the single dipole magnet (x32) or the two or more dipole magnets (x32) are located partially within, within or above the loop defined by the single loop-shaped magnet (x31) or partially within, within or above the loop

defined by the two or more dipole magnets (x31) disposed in the loop-shaped arrangement, and wherein the South pole of said single dipole magnet (x32) or the South pole of each of said two or more dipole magnets (x32) is pointing towards the substrate surface when the North pole of the single loop-shaped magnet (x31) or of the two or more dipole magnets (x31) forming the loop-shaped magnetic-field generating device (x31) is pointing towards the periphery of said loop-shaped magnetic-field generating device (x31) or the North pole of said single dipole magnet (x32) or the North pole of each said two or more dipole magnets (x32) is pointing towards the substrate surface when the South pole of the single loop-shaped magnet (x31) or of the two or more dipole magnets (x31) forming the loop-shaped magnetic-field generating device (x31) is pointing towards the periphery of said loop-shaped magnetic-field generating device (x31).

[0095] According to one embodiment, the process described herein allows the preparation of OELs wherein the first motif exhibits a dynamic motion upon tilting said OEL, said dynamic movement being a moon crescent moving and rotating when the OEL is tilted; wherein said step b') consists of exposing the first radiation curable coating composition to a magnetic assembly such as those disclosed in WO 2019/215148 A1. Disclosed magnetic assemblies of WO 2019/215148 A1 comprise a) a first magnetic-field generating device (x30) having its North-South magnetic axis substantially perpendicular to the substrate surface and having length L1, b) a second magnetic-field generating device (x40) having its North-South magnetic axis substantially perpendicular to the substrate and having a length L3, and c) a flat pole piece (x50) lacking any protrusions or projections extending outside the surface of said pole piece and having a length L5, wherein the first magnetic-field generating device and the second magnetic-field generating device have a same magnetic field direction, wherein the first magnetic-field generating device faces the substrate and is disposed above the flat pole piece, wherein the second magnetic-field generating device faces the environment and is disposed below the flat pole piece, wherein the length L1 of the first magnetic-field generating device is smaller than the length L3 of the second magnetic-field generating device, wherein the length L1 of the first magnetic-field generating device is smaller than the length L5 of the flat pole piece, and wherein the length L3 of the second magnetic-field generating device is smaller than the length L5 of the pole piece (see for example Figs 1-12 of WO 2017/148789 A1).

[0096] According to one embodiment, the process described herein allows the preparation of OELs wherein the first motif exhibits a dynamic motion upon tilting said OEL, said dynamic movement being a loop-shaped body surrounded by a substantially loop-shaped body having their shape and/or their brightness varying when the OEL is tilted; wherein said step b') consists of exposing the first radiation curable coating composition to a magnetic assembly such as those disclosed in WO 2020/193009 A1. Disclosed magnetic assemblies of WO 2020/193009 A1 comprise a) a combination of three or more first dipole magnets (x31-ai), each of said first dipole magnets having its center disposed on a loop in a plane parallel to the substrate, wherein said first dipole magnets (x31-ai) have their magnetic axes oriented to be substantially parallel to the substrate and b) at least one second dipole magnet (x41) having its magnetic axis oriented to be substantially perpendicular to the substrate and being arranged to have a projection of its center on the substrate be located at a projection point within the loop, wherein the at least one second dipole magnet (x41) is disposed above the combination of three or more first dipole magnets (x31-ai), wherein angles α_i are formed between each of the vectors

$\overrightarrow{C_{x41}C_{x31-ai}}$, $\overrightarrow{C_{x41}C_{x31-a1}}$, $\overrightarrow{C_{x41}C_{x31-a2}}$, $\overrightarrow{C_{x41}C_{x31-a3}}$ and the vector $\overrightarrow{h_{x31-ai}}$ ($\overrightarrow{h_{x31-a1}}$, $\overrightarrow{h_{x31-a2}}$, $\overrightarrow{h_{x31-a3}}$, ...) of the magnetic axis of the respective first dipole magnet magnets (x31-ai), wherein all of the angles α_i , when measured in a counterclockwise direction, are in a range from about 20° to about 160° or in a range from about 200° to about 340°, and wherein each of the first dipole magnets (x31-ai) is disposed at a first distance (Y_i), said first distance (Y_i) being on the substrate between the projection point and the center of the first dipole magnet (x31-ai) (see for example Figs 2-9 of in WO 2020/193009 A1).

[0097] According to one embodiment, the process described herein allows the preparation of OELs wherein the first motif exhibits a dynamic motion upon tilting said OEL, said dynamic movement being a change from dark to light of two areas when the OEL is tilted (effect so-called flip-flop); wherein said step b') consists of exposing the first radiation curable coating composition to a magnetic assembly such as those disclosed in Figs 1, 3 and 6 of US 2005/0106367.

[0098] According to one embodiment, the process described herein allows the preparation of OELs wherein the first motif exhibits a dynamic motion upon tilting said OEL, said dynamic movement being a comet-shaped spot rotating around said center of rotation upon tilting said OEL, wherein said step b') consists of exposing the first radiation curable coating composition to a magnetic assembly such as those disclosed in WO 2019/038371 A1, WO 2019/ 038370 A1 and WO 2019/038369 A1. Disclosed magnetic assemblies of WO 2019/038371 A1, WO 2019/ 038370 A1 and WO 2019/038369 A1 comprise at least one of the following:

- a) first magnetic-field generating device (x30) and b) a second magnetic-field generating device (x40), wherein said first magnetic-field generating device (x30) and said second magnetic-field generating device (x40) have mutually skew magnetic axes, wherein said first magnetic-field generating device (x30) has its magnetic axis substantially perpendicular to the axis of spinning and said second magnetic-field generating device (x40) has its magnetic axis substantially perpendicular to the axis of spinning and wherein the projection of the magnetic axis of the first magnetic-

field generating device (x30) and the projection of the magnetic axis of the second magnetic-field generating device (x40) along the axis of spinning onto a plane perpendicular to the axis of spinning form an angle (Ω) either in the range from about 5° to about 175° or in the range from about -5° to about -175° , and wherein the first magnetic-field generating device (x30) comprises a bar dipole magnet having its North-South magnetic axis substantially perpendicular to the axis of spinning, or two or more bar dipole magnets, each of said two or more bar dipole magnets having its North-South magnetic axis substantially perpendicular to the axis of spinning and all of said two or more bar dipole magnets having a same magnetic field direction, or a loop-shaped dipole magnet having its North-South magnetic axis substantially perpendicular to the axis of spinning, or a disc-shaped dipole magnet being nested inside a loop-shaped dipole magnet, each of the disc-shaped dipole magnet and the loop-shaped dipole magnets having their North-South magnetic axis substantially perpendicular to the axis of spinning and having a same magnetic field direction, or two or more nested loop-shaped dipole magnets, each of said two or more nested loop-shaped dipole magnets, having its North-South magnetic axis substantially perpendicular to the axis of spinning and all of said two or more nested ring-shaped magnets having a same magnetic field direction; and wherein the second magnetic-field generating device (x40) comprises a disc-shaped dipole magnet having its North-South magnetic axis substantially perpendicular to the axis of spinning, or a loop-shaped dipole magnet having its North-South magnetic axis substantially perpendicular to the axis of spinning, or a bar dipole magnet having its North-South magnetic axis substantially perpendicular to the axis of spinning;

- a first magnetic-field generating device (x30) and b) a second magnetic-field generating device (x40), wherein the first magnetic-field generating device (x30) comprises at least one pair of two bar dipole magnets (x31) at least partially or fully embedded in a supporting matrix (x32), each of said bar dipole magnets (x31) having its North-South magnetic axis substantially parallel to the axis of spinning, said two bar dipole magnets (x31) of the at least one pair having opposite magnetic field directions and being arranged in a symmetric configuration around the axis of spinning along a line (α), and

the second magnetic-field generating device (x40) comprises b1) a disc-shaped dipole magnet (x41) having its North-South magnetic axis substantially perpendicular to the axis of spinning, b2) a loop-shaped dipole magnet (x41) having its North-South magnetic axis substantially perpendicular to the axis of spinning, b3) a bar dipole magnet (x41) having its North-South magnetic axis substantially perpendicular to the axis of spinning and arranged on the axis of spinning, and/or b4) at least one pair of two bar dipole magnets (x41), each of said bar dipole magnets (x41) having its North-South magnetic axis substantially parallel to the axis of spinning, said two bar dipole magnets (x41) of the at least one pair having opposite magnetic field directions and being arranged in a symmetric configuration around the axis of spinning along a line (β), wherein the projection of the line (α) where the bar dipole magnets (x31) of the at least one pair of the first magnetic-field generating device (x30) are arranged and the projection of the magnetic axis of the second magnetic-field generating device (x40) form along the axis of spinning onto a plane perpendicular to the axis of spinning an angle (Ω) either in the range from about 5° to about 175° or in the range from about -5° to about -175° ; or

- a magnetic-field generating device (x30) comprising a disc-shaped dipole magnet (x31) having its North-South magnetic axis substantially perpendicular to the axis of spinning, or a loop-shaped, preferably a ring-shaped, dipole magnet (x31) having its North-South magnetic axis substantially perpendicular to the axis of spinning, or a bar dipole magnet (x31) having its North-South magnetic axis substantially perpendicular to the axis of spinning and arranged on the axis of spinning, wherein the disc-shaped dipole magnet (x31), the loop-shaped, preferably the ring-shaped, dipole magnet (x31) or the bar dipole magnet (x31) of the magnetic-field generating device (x30) comprises at least one pair of indentations (I) and/or at least one pair of voids (V) and/or at least one pair of protrusions (P), wherein the indentations (I) of the at least one pair, the voids (V) of the at least one pair and/or the protrusions (P) of the at least one pair are located: symmetrically about the axis of spinning, and asymmetrically with respect to a mirror plane which is perpendicular to the North-South magnetic axis of the disc-shaped dipole magnet (x31), the loop-shaped, preferably the ring-shaped, dipole magnet (x31) or the bar dipole magnet (x31) of the magnetic-field generating device (x30) and which contains the axis of spinning.

[0099] According to one embodiment, the process described herein allows the preparation of OELs, wherein step b') consists of independently exposing the first radiation curable coating composition to the resultant magnetic field of a combination of a magnetic assembly described hereafter for bi-axially orienting pigment particles and a soft magnetic plate comprising one or more indentations (I) and/or one or more voids (V) and/or one or more protrusions (P). The soft magnetic plate described herein comprises one or more soft magnetic materials, i.e. materials having a low coercivity and a high permeability μ . Their coercivity is lower than 1000 Am^{-1} as measured according to IEC 60404-1 :2000, to allow for a fast magnetization and demagnetization. Suitable soft magnetic materials have a maximum relative permeability $\mu_{R \max}$ of at least 5, where the relative permeability μ_R is the permeability of the material μ relative to the permeability of the free space μ_0 ($\mu_R = \mu / \mu_0$) (Magnetic Materials, Fundamentals and Applications, 2nd Ed., Nicola A. Spaldin, p. 16-17, Cambridge University Press, 2011). Soft magnetic materials are described, for example, in the following hand-

books: (1) Handbook of Condensed Matter and Materials Data, Chap. 4.3.2, Soft Magnetic Materials, p. 758-793, and Chap. 4.3. 4, Magnetic Oxides, p. 811-813, Springer 2005; (2) Ferromagnetic Materials, Vol. 1, Iron, Cobalt and Nickel, p. 1-70, Elsevier 1999; (3) Ferromagnetic Materials, Vol. 2, Chap. 2, Soft Magnetic Metallic Materials, p. 55-188, and Chap. 3, Ferrites for non-microwave Applications, p. 189-241, Elsevier 1999; (4) Electric and Magnetic Properties of Metals, C. Moosbrugger, Chap. 8, Magnetically Soft Materials, p. 196-209, ASM International, 2000; (5) Handbook of modern Ferromagnetic Materials, Chap. 9, High-permeability High-frequency Metal Strip, p. 155-182, Kluwer Academic Publishers, 2002; and (6) Smithells Metals Reference Book, Chap. 20.3, Magnetically Soft Materials, p. 20-9 - 20-16, Butterworth-Heinemann Ltd, 1992. The soft magnetic plate described herein may either be a plate made of one or more metals, alloys or compounds of high magnetic permeability (hereafter referred as "soft magnetic metal plate") or a plate made of a composite comprising soft magnetic particles dispersed in a non-magnetic material (hereafter referred as "soft magnetic composite plate"). According to one embodiment, the soft magnetic metal plate described herein is made of one or more soft magnetic metals or alloys easily workable as sheets or threads. Preferably, the soft magnetic metal plate described herein is made from one or more materials selected from the group consisting of iron, cobalt, nickel, nickel-molybdenum alloys, nickel-iron alloys (permalloy or supermalloy-type materials), cobalt-iron alloys, cobalt-nickels alloys iron-nickel-cobalt alloys (Fernico-type materials), Heusler-type alloys (such as Cu_2MnSn or Ni_2MnAl), low silicon steels, low carbon steels, silicon irons (electrical steels), iron-aluminum alloys, iron-aluminum-silicon alloys, amorphous metal alloys (e.g. alloys like Metglas[®], iron-boron alloys), nanocrystalline soft magnetic materials (e.g. Vitroperm[®]) and combinations thereof, more preferably selected from the group consisting of iron, cobalt, nickel, low carbon steels, silicon irons, nickel-iron alloys and cobalt-iron alloys and combinations thereof.

[0100] According to one embodiment, the process described herein comprises the bi-axial orientation step b") consisting of a one-step orientation step.

[0101] Contrary to a mono-axial orientation wherein platelet-shaped magnetic or magnetizable pigment particles are orientated in such a way that only their main axis is constrained by the magnetic field, carrying out a bi-axial orientation means that the platelet-shaped magnetic or magnetizable pigment particles are made to orientate in such a way that their two main axes are constrained. In contrast to needle-shaped pigment particles which can be considered as one-dimensional particles, platelet-shaped pigment particles have an X-axis and a Y-axis defining a plane of predominant extension of the particles. In other words, platelet-shaped pigment particles may be considered to be two-dimensional particles due to the large aspect ratio of their dimensions as can be seen in Fig. 2. As shown in Fig. 2, a platelet-shaped pigment particle can be considered as a two-dimensional structure wherein the dimensions X and Y are substantially larger than dimension Z. Platelet-shaped pigment particles are also referred in the art as oblate particles or flakes. Such pigment particles may be described with a main axis X corresponding to the longest dimension crossing the pigment particle and a second axis Y perpendicular to X which also lies within said pigment particles. Carrying out a bi-axial orientation leads to platelet-shaped magnetic or magnetizable pigment particles having two main axes constrained, i.e. bi-axially oriented neighboring platelet-shaped magnetic pigment particles are close to each other in space and are essentially parallel to each other. Put another way, bi-axial orientation aligns the planes of the platelet-shaped magnetic or magnetizable pigment particles so that the planes of said pigment particles are oriented to be essentially parallel relative to the planes of neighboring (in all directions) platelet-shaped magnetic or magnetizable pigment particles.

[0102] Bi-axially oriented platelet-shaped magnetic or magnetizable pigment particles described herein consist of platelet-shaped magnetic or magnetizable pigment particles forming a sheet-like structure with their X and Y axes preferably substantially parallel to the substrate (x10) surface and are planarized in said two dimensions.

[0103] According to another embodiment, the magnetic assembly described hereafter allow to biaxially orient the platelet-shaped magnetic or magnetizable pigment particles described herein such that the platelet-shaped magnetic or magnetizable pigment particles have both their X-axis and Y-axis substantially parallel to the substrate (x10) surface.

[0104] According to another embodiment, the magnetic assembly described hereafter allow to biaxially orient the platelet-shaped magnetic or magnetizable pigment particles described herein such that the platelet-shaped magnetic or magnetizable pigment particles have their X-Y plane substantially parallel to an imaginary spheroid surface.

[0105] According to another embodiment, the magnetic assembly described hereafter allow to biaxially orient the platelet-shaped magnetic or magnetizable pigment particles described herein such that the platelet-shaped magnetic or magnetizable pigment particles have a first axis within the X-Y plane substantially parallel to the substrate (x10) surface and a second axis being perpendicular to said first axis at a substantially non-zero elevation angle to the substrate (x10) surface, or iii) have their X-Y plane parallel to an imaginary spheroid surface.

[0106] According to one embodiment, the process described herein comprises the orientation step b") consisting of a one-step orientation step to bi-axially orient the magnetic or magnetizable pigment particles described herein so that i) they have both their X-axis and Y-axis substantially parallel to the substrate (x10) surface, or ii) have their X-Y plane parallel to an imaginary spheroid surface.

[0107] According to one embodiment shown for example in Fig. 7A, the orientation step b") of the second set of steps (S2) is a one-step orientation step, wherein the substrate (710) carrying the first coating layer (720') and the second coating layer (720") on its same side is exposed to the magnetic field of a magnetic assembly (730") being positioned

on the side of the substrate (710) lacking the first and second coating layers (720' and 720"). Fig. 7C (not true to scale) illustrates a process wherein the orientation step b") consists of a one-step orientation step, wherein the substrate (710) carrying the first and second coating layers (720' and 720") on its same side is exposed to the magnetic field of a static magnetic assembly (730"), wherein said magnetic assembly (730") is arranged in the vicinity of a rotating cylinder (2 positions are shown in Fig. 7C), wherein the second coating layer (720") is exposed either to one and/or the other of said magnetic assemblies (730").

[0108] According to one embodiment shown for example in Fig. 7B, the orientation step b") of the second set of steps (S2) is a one-step orientation step, wherein the substrate (710) carrying the first coating layer (720') on a first side and the second coating layer (720") on a second side of the substrate (710) (i.e. the side of the substrate (710) lacking the first coating layer (720')) is exposed to the magnetic field of a magnetic assembly (730") being positioned on the side comprising the cured first coating layer (720').

[0109] According to one embodiment shown for example in Fig. 8A, the orientation step b") of the second set of steps (S2) is a one-step orientation step, wherein the substrate (810) carrying the first coating layer (820') and the second coating layer (820") on its same side is exposed to the magnetic field of a spinning magnetic assembly (830") being positioned on the side of the substrate (810) lacking the first and second coating layers (820' and 820"). Fig. 8C (not true to scale) illustrates a process wherein the orientation step b") consists of a one-step orientation step, wherein the substrate (810) carrying the first and second coating layers (820' and 820") described herein is exposed to the magnetic field of a spinning magnetic assembly (830"), wherein said magnetic assembly (830") is mounted on a rotating cylinder.

[0110] According to one embodiment shown for example in Fig. 8B, the orientation step b") of the second set of steps (S2) is a one-step orientation step, wherein the substrate (810) carrying the first coating layer (820') on a first side and the second coating layer (820") on a second side of the substrate (810) (i.e. the side of the substrate (810) lacking the first coating layer (820')) is exposed to the magnetic field of a spinning magnetic assembly (830") being positioned on the side comprising the cured first coating layer (820').

[0111] According to one embodiment shown in Fig. 9, the process described herein comprises a third set of steps (S3), said third set of steps (S3) occurring after the second set (S2), said a third set of steps (S3) comprising an orientation step b''') consisting of a one-step orientation step, wherein the substrate (910) carrying the first coating layer (920') and the second coating layer (920") on a first and same side and carrying a third coating layer (920") on a second side of the substrate (910) (i.e. the side of the substrate lacking the first and second coating layers (920' and 920")) is exposed to the magnetic field of a spinning magnetic assembly (930") being positioned on the side of the substrate (910) comprising the first and second cured coating layers (920' and 920").

[0112] Suitable magnetic assemblies for bi-axially orienting the platelet-shaped magnetic or magnetizable pigment particles described herein are provided hereafter as non-limiting examples.

[0113] According to one embodiment shown for example in Fig. 10 (Example E1-E5, magnetic assembly (1030) used during steps b') and Example E1 during step b'')), bi-axially orientation is carried out by exposing the radiation curable coating composition to a magnetic assembly such as those disclosed in WO 2021/239607 A1. The disclosed magnetic assemblies of WO 2021/239607 A1 comprise:

- a) at least a first set (S1) and a second set (S2), each of the first and second sets (S1, S2) comprising: i) one first bar dipole magnet (x31) having a first thickness (L1), a first length (L4) and a first width (L5), and having its magnetic axis oriented to be substantially parallel to the substrate, and ii) two second bar dipole magnets (x32_a and x32_b) having a second thickness (L2), a second length (L6) and a second width (L7), the two second bar dipole magnets (x32_a, x32_b) having their uppermost surfaces flush with each other, and having their magnetic axes oriented to be substantially perpendicular to the substrate, wherein the first bar dipole magnet (x31) of the first set (S1) has a magnetic direction opposite to the magnetic direction of the first bar dipole magnet (x31) of the second set (S2), the first bar dipole magnets (x31) of the first and second sets (S1, S2) is spaced apart by a first distance (d1), the first bar dipole magnet (x31) of the first set (S1) has substantially the same first length (L4) and first width (L5) as the first bar dipole magnet (x31) of the second set (S2), and the two second bar dipole magnets (x32_a and x32_b) of the first set (S1) has substantially the same second lengths (L6) and second widths (L7) as the two second bar dipole magnets (x32_a and x32_b) of the second set (S2), wherein the first bar dipole magnet (x31) and the second bar dipole magnets (x32_a and x32_b) of each of the first and second sets (S1, S2) are aligned to form a column, in that the first bar dipole magnet (x31) of the first and second sets (S1, S2) is respectively placed between and spaced apart from the second bar dipole magnets (x32_a and x32_b) by a second distance (d2), the first width (L5) and the second length (L6) being substantially the same, the North pole of one second bar dipole magnet (x32_a and x32_b) of each of the first and second sets (S1, S2) pointing towards the first plane as the North Pole of the first bar dipole magnet (x31) pointing towards said one, and the South pole of the other of the second bar dipole magnet (x32_a and x32_b) of each of the first and second sets (S1, S2) pointing towards the first plane and the South Pole of the first bar dipole magnet (x31) pointing towards said other; and
- b) a first pair (P1) of third bar dipole magnets (x33_a and x33_b) having a third thickness (L3), a third length (L8) and

a third width (L9) and having their magnetic axes oriented to be substantially parallel to the substrate, the second width (L7) of the two second bar dipole magnets ($x32_a$ and $x32_b$) of the first and second sets (S1, S2) having substantially the same value as the third width (L9) of the third bar dipole magnets ($x33_a$ and $x33_b$), each of the third bar dipole magnets ($x33_a$ and $x33_b$) being aligned with one second bar dipole magnet ($x32_a$ and $x32_b$) of the first set (S1) and one second bar dipole magnet ($x32_a$ and $x32_b$) of the second set (S2) so as to form two lines, the third bar dipole magnets ($x33_a$ and $x33_b$) being placed between and spaced apart from the respective second bar dipole magnets ($x32_a$ and $x32_b$) by a third distance (d3), the North poles of the third bar dipole magnets ($x33_a$ and $x33_b$) respectively pointing towards one of the second bar dipole magnets ($x32_a$ and $x32_b$) when the North Poles of said ones of the second bar dipole magnets ($x32_a$ and $x32_b$) point towards the substrate or the South poles of the third bar dipole magnets ($x33_a$ and $x33_b$) respectively pointing towards one of the second bar dipole magnets ($x32_a$ and $x32_b$) when the South Poles of said ones of the second bar dipole magnets ($x32_a$ and $x32_b$) pointing towards the substrate.

[0114] According to one embodiment, the process described herein comprises i) steps b") or ii) both steps b") and b') or iii) both steps b") and b'") independently consisting of exposing the radiation curable coating composition to a magnetic assembly such as those described in EP 2 157 141 A1. The disclosed magnetic assemblies of EP 2 157 141 A1 provide a magnetic field that changes its direction while the platelet-shaped magnetic or magnetizable pigment particles move through said assemblies, forcing the platelet-shaped magnetic or magnetizable pigment particles to rapidly oscillate until both main axes become parallel to the substrate, i.e. the platelet-shaped magnetic or magnetizable pigment particles oscillate until they come to a stable sheet-like formation with their X and Y axes parallel to the substrate and are planarized in said two dimensions. As shown in Fig. 5 of EP 2 157 141, the magnetic assembly comprises a linear arrangement of at least three magnets that are positioned in a staggered fashion or in zigzag formation, said at least three magnets being on opposite sides of a feedpath where magnets at the same side of the feedpath have the same polarity, which is opposed to the polarity of the magnet(s) on the opposing side of the feedpath in a staggered fashion. The arrangement of the at least three magnets provides a predetermined change of the field direction as platelet-shaped magnetic or magnetizable pigment particles in a coating composition move past the magnets (direction of movement: arrow). According to one embodiment, the magnetic assembly comprises a) a first magnet and a third magnet on a first side of a feedpath and b) a second magnet between the first and third magnets on a second opposite side of the feedpath, wherein the first and third magnets have a same polarity and wherein the second magnet has a complementary polarity to the first and third magnets. According to another embodiment, the magnetic assembly further comprises a fourth magnets on the same side of the feedpath as the second magnet, having the polarity of the second magnet and complementary to the polarity of the third magnet.

[0115] According to one embodiment, bi-axially orientation is carried out by exposing the radiation curable coating composition to a magnetic assembly consisting of a linear permanent magnet Halbach array, i.e. assemblies comprising a plurality of magnets with different magnetization directions and cylinder devices. A detailed description of Halbach permanent magnets was given by Z.Q. Zhu and D. Howe (Halbach permanent magnet machines and applications: a review, IEE. Proc. Electric Power Appl., 2001, 148, p. 299-308). The magnetic field produced by such a Halbach array has the properties that it is concentrated on one side while being weakened almost to zero on the other side. Linear Halbach arrays are disclosed for example in WO 2015/086257 A1 and WO 2018/019594 A1 and Halbach cylinder devices are disclosed in EP 3 224 055 B1.

[0116] According to one embodiment, bi-axially orientation is carried out by exposing the radiation curable coating composition to spinning magnetic assemblies at an appropriate speed. Examples of spinning magnetic assemblies are assemblies comprising one or more disc-shaped spinning magnets or magnetic assemblies that are essentially magnetized along their diameter. magnetic assemblies consisting of spinning magnets or magnetic-field generating devices are described in US 2007/0172261 A1, said spinning magnets or magnetic-field generating devices generating radially symmetrical time-variable magnetic fields, allowing the bi-axial orientation of pigment particles. These magnetic assemblies are driven by a shaft (or spindle) connected to an external motor. CN 102529326 B discloses examples of magnetic assemblies comprising spinning magnets that might be suitable for bi-axially orienting pigment particles. In a preferred embodiment, suitable magnetic assemblies are shaft-free disc-shaped spinning magnetic assemblies constrained in a housing made of non-magnetic, preferably non-conducting, materials and are driven by one or more magnet-wire coils wound around the housing. Examples of such shaft-free disc-shaped spinning magnetic assemblies are disclosed in WO 2015/082344 A1 and WO 2016/026896 A1.

[0117] According to one embodiment shown for example in Figs. 12-13, the bi-axially orientation step is carried out by exposing the radiation curable coating composition to the spinning magnetic assemblies disclosed in WO2018/141547 A1 at an appropriate speed. The disclosed magnetic assemblies (x30) of WO2018/141547 A1 comprise

a) a first block (A) comprising a1) a holder (1a) having mounted thereto a stator comprising n magnet-wire coils (1b) disposed in n annular slots arranged in a circle around the axis of a magnetic-field-guiding stator core (1c); and

b) a second block (B) comprising:

b1) a casing (4)

b2) a rotor comprising m permanent magnet poles (3a) of alternating polarity arranged around a circle in or on one side of a rotor disc (3b), wherein said m permanent magnet poles (3a) face the rotor protection plate (2);
b3) a rotor protection plate (2), preferably a titanium rotor protection plate (2), wherein said rotor protection plate (2) covers the rotor (3a + 3b); and

b4) a permanent magnet assembly (PMA) (5) driven by the rotor (3a + 3b), wherein said permanent magnet assembly (PMA) (5) is disposed on the opposite side of the rotor disc (3b),

wherein the stator (1b + 1c) and the rotor (3a + 3b) act together as a brushless DC (BLDC) motor, wherein n is a multiple of 3 and m is a multiple of 2, provided that n/m is 3/2, 3/4, 6/4, 6/8, 9/8, 9/10, 12/10 or 12/14, and wherein the first block (A) is configured to be removeably fixed to a base of a rotating magnetic orienting cylinder (RMC) or a flatbed (FB) magnetic orienting printing unit, and

wherein the second block (B) is removeably fixed to the first block (A).

[0118] According to one embodiment, the orientation step b") of the second set of steps (S2) is a two-steps orientation step, with a first step so as to bi-axially orient at least a part of the platelet-shaped magnetic or magnetizable pigment particles such as those described herein and a second step so as to bi-axially orient at least a part of the platelet-shaped magnetic or magnetizable pigment particles such as those described herein, wherein the magnetic assemblies (x30") used in both steps may be the same or may be different.

[0119] According to one embodiment, the process described herein comprises a third set of steps (S3), wherein the orientation step b'") consists of exposing a third radiation curable coating composition of step a'") to a magnetic field of a magnetic assembly (x30'") so as to bi-axially orient at least a part of the platelet-shaped magnetic or magnetizable pigment particles to i) have both their X-axis and Y-axis substantially parallel to the substrate (x10) surface, or ii) have their X-Y plane parallel to an imaginary spheroid surface, and form a third coating layer (x20'") and a third magnetic pattern, said third coating layer (x20'") being adjacent to and in proper register with at least a part of the first motif and/or adjacent to and in proper register with at least a part of the second motif (i.e. the third motif is at least partially adjacent to and in proper register with the first coating layer (x20') and/or adjacent to and in proper register with at least a part of the second coating layer (x20"), wherein said third magnetic pattern may be the same as the second magnetic pattern or may be different from the second magnetic pattern.

[0120] According to one embodiment, the orientation step b'") of the third set of steps (S3) is a one-step orientation step or a two-steps orientation step such as those described for step b') or for step b"). Preferably, the orientation step b'") of the third set of steps (S3) is a one-step orientation step such as those described for step b") of the second set of steps (S2), wherein the so-obtained third magnetic pattern is the same as the second magnetic pattern or different from the second magnetic pattern.

[0121] Also described herein are the following combinations of sets of steps:

- the first set of steps (S1) comprising the step b') and the second set (S2) comprising the step b"), both independently consisting of one-step orientation steps as described herein;
- the first set of steps (S1) comprising the step b') consisting of a two-steps orientation step as described herein, preferably a two-steps orientation step independently comprising a first orienting step to bi-axially orient the platelet-shaped magnetic or magnetizable pigment particles followed by a second orienting step to re-orient the platelet-shaped magnetic or magnetizable pigment particles described herein and the second set of steps (S2) comprising the step b") consisting of a one-step orientation step as described herein to bi-axially orient the platelet-shaped magnetic or magnetizable pigment particles; and
- the first set of steps (S1) comprising the step b') and the second set of steps (S2) comprising the step b"), both independently consisting of two-steps orientation steps, the steps of b') consisting of first orienting step to bi-axially orient the platelet-shaped magnetic or magnetizable pigment particles followed by the second orienting step to re-orient the platelet-shaped magnetic or magnetizable pigment particles described herein and the steps b") consisting of first orienting step to bi-axially orient the platelet-shaped magnetic or magnetizable pigment particles followed by the second orienting step to bi-axially orient the platelet-shaped magnetic or magnetizable pigment particles described herein,
- the first set of steps (S1) comprising the step b'), the second set (S2) comprising the step b") and the third set of steps (S3) comprising the step b'"), the three independently consisting of one-step orientation steps as described herein;
- the first set of steps (S1) comprising the step b') consisting of the two-steps orientation steps as described herein, preferably the two-steps orientation steps independently comprising the first orienting step to bi-axially orient the platelet-shaped magnetic or magnetizable pigment particles followed by the second orienting step to re-orient the

platelet-shaped magnetic or magnetizable pigment particles described herein; the second set of steps (S2) comprising the step b'') consisting of a one-step orientation step as described herein; and the third set of steps (S3) comprising the step b''') consisting of a one-step orientation step as described herein;

- the first set of steps (S1) comprising the step b') and the second set of steps (S2) comprising the step b''), both independently consisting of two-steps orientation steps, the steps of b') consisting of first orienting step to bi-axially orient the platelet-shaped magnetic or magnetizable pigment particles followed by the second orienting step to re-orient the platelet-shaped magnetic or magnetizable pigment particles described herein and the steps b'') consisting of first orienting step to bi-axially orient the platelet-shaped magnetic or magnetizable pigment particles followed by the second orienting step to bi-axially orient the platelet-shaped magnetic or magnetizable pigment particles described herein and the third set of steps (S3) comprising the step b''') consisting of a one-step orientation step as described herein; and
- the first set of steps (S1) comprising the step b'), the second set of steps (S2) comprising the step b'') and the third set of steps (S3) comprising the step b'''), the three steps independently consisting of two-steps orientation steps, the steps of b') consisting of first orienting step to bi-axially orient the platelet-shaped magnetic or magnetizable pigment particles followed by the second orienting step to re-orient the platelet-shaped magnetic or magnetizable pigment particles described herein, the step b'') consisting of first orienting step to bi-axially orient the platelet-shaped magnetic or magnetizable pigment particles followed by the second orienting step to bi-axially orient the platelet-shaped magnetic or magnetizable pigment particles described herein and the third set of steps (S3) comprising the step b''') consisting of first orienting step to bi-axially orient the platelet-shaped magnetic or magnetizable pigment particles followed by the second orienting step to bi-axially orient the platelet-shaped magnetic or magnetizable pigment particles described herein.

[0122] Subsequently to or partially simultaneously with, preferably partially simultaneously with, the steps of orienting the platelet-shaped magnetic or magnetizable pigment particles described herein (step b') and step b'') and optional step b'''), the orientation of the platelet-shaped magnetic or magnetizable pigment particles is independently fixed or frozen (step c'), step c'') and optional step c''') by curing. The first and second coating compositions, optionally the third coating composition, must thus noteworthy have a first state, i.e. a liquid or pasty state, wherein the compositions are not yet hardened and wet or soft enough, so that the platelet-shaped magnetic or magnetizable pigment particles dispersed in the compositions are freely movable, rotatable and orientable upon exposure to a magnetic field, and a second hardened (e.g. solid or solid-like) state, wherein the platelet-shaped magnetic or magnetizable pigment particles are fixed or frozen in their respective positions and orientations.

[0123] Such a first and second state is preferably provided by using a certain type of coating compositions. For example, the components of the first and second radiation curable coating composition other than the platelet-shaped magnetic or magnetizable pigment particles may take the form of an ink or coating composition such as those which are used in security applications, e.g. for banknote printing. The aforementioned first and second states can be provided by using a material that shows an increase in viscosity in reaction to a stimulus such as for example a temperature change or an exposure to an electromagnetic radiation. That is, when the fluid binder material is hardened or solidified, said binder material converts into the second state, i.e. a hardened or solid state, where the platelet-shaped magnetic or magnetizable pigment particles are fixed in their current positions and orientations and can no longer move nor rotate within the binder material. As known to those skilled in the art, ingredients comprised in an ink or coating composition to be applied directly or indirectly onto a substrate and the physical properties of said ink or coating composition must fulfil the requirements of the process used to transfer said ink or coating composition. Consequently, the binder material comprised in the coating compositions described herein is typically chosen among those known in the art and depends on the coating or printing process used to apply the ink or coating composition and the chosen hardening process.

[0124] The curing steps described herein (step c'), step c'') and optional step c''') independently involve a chemical reaction, for instance curing, which is not reversed by a simple temperature increase (e.g. up to 80°C) that may occur during a typical use of a security document. The term "curing" or "curable" refers to processes including the chemical reaction, crosslinking or polymerization of at least one component in the applied coating composition in such a manner that it turns into a polymeric material having a greater molecular weight than the starting substances. Preferably, the curing causes the formation of a stable three-dimensional polymeric network. Such a curing is generally induced by applying an external stimulus to the compositions (i) after its application (step a'), step a'') and optional step a''') and (ii) subsequently to or partially simultaneously with the orientation (step b'), step b'') and optional step b''') of at least part of the platelet-shaped magnetic or magnetizable pigment particles (step c'), step c'') and optional step c'''). Advantageously the curing steps (step c'), step c'') and optional step c''') of the first and second coating layers (x20' and x20'') and optional third coating layer (x20''') described herein is independently carried out partially simultaneously with the orientation (step b'), step b'') and optional step b''') of at least a part of the platelet-shaped magnetic or magnetizable pigment particles (step c'), step c'') and optional step c'''). Radiation curing, in particular UV-Vis curing, advantageously leads to an instantaneous increase in viscosity of the first and second radiation curable coating compositions after

exposure to the irradiation, thus preventing any further movement of the pigment particles and in consequence any loss of information after the magnetic orientation steps. Preferably, the curing steps (step c'), step c'') and optional step c''') are independently carried out by irradiation with UV-visible light (i.e. UV-Vis light radiation curing) or by E-beam (i.e. E-beam radiation curing), more preferably by irradiation with UV-Vis light since UV-Vis curing advantageously allows very fast curing processes and hence drastically decreases the preparation time of the OEL described herein, documents and articles and documents comprising said OEL.

[0125] Preferably, the first or the second or the optional third radiation curable coating compositions, preferably the first and the second and the third UV-Vis-curable curable coating compositions, independently comprise one or more compounds selected from the group consisting of radically curable compounds and cationically curable compounds. The compositions described herein may be hybrid systems and comprise a mixture of one or more cationically curable compounds and one or more radically curable compounds. Cationically curable compounds are cured by cationic mechanisms typically including the activation by radiation of one or more photoinitiators which liberate cationic species, such as acids, which in turn initiate the curing so as to react and/or cross-link the monomers and/or oligomers to thereby harden the coating composition. Radically curable compounds are cured by free radical mechanisms typically including the activation by radiation of one or more photoinitiators, thereby generating radicals which in turn initiate the polymerization so as to harden the coating composition. Depending on the monomers, oligomers or prepolymers used to prepare the binder comprised in the first and second radiation curable coating compositions described herein, different photoinitiators might be used. Suitable examples of free radical photoinitiators are known to those skilled in the art and include without limitation acetophenones, benzophenones, benzoyldimethyl ketals, alpha-aminoketones, alpha-hydroxyketones, phosphine oxides and phosphine oxide derivatives, as well as mixtures of two or more thereof. Suitable examples of cationic photoinitiators are known to those skilled in the art and include without limitation onium salts such as organic iodonium salts (e.g. diaryl iodonium salts), oxonium (e.g. triaryloxonium salts) and sulfonium salts (e.g. triarylsulphonium salts), as well as mixtures of two or more thereof. Other examples of useful photoinitiators can be found in standard textbooks. It may also be advantageous to include a sensitizer in conjunction with the one or more photoinitiators in order to achieve efficient curing. Typical examples of suitable photosensitizers include without limitation isopropylthioxanthone (ITX), 1-chloro-2-propoxy-thioxanthone (CPTX), 2-chloro-thioxanthone (CTX) and 2,4-diethyl-thioxanthone (DETX) and mixtures of two or more thereof. The one or more photoinitiators comprised in the UV-Vis-curable coating compositions are preferably present in a total amount from about 0.1 wt-% to about 20 wt-%, more preferably about 1 wt-% to about 15 wt-%, the weight percents being based on the total weight of the first and second radiation curable coating compositions, respectively.

[0126] The first, the second and the third radiation curable coating compositions described herein may further independently comprise one or more additives including without limitation compounds and materials which are used for adjusting physical, rheological and chemical parameters of the composition such as the viscosity (e.g. solvents and surfactants), the consistency (e.g. anti-settling agents, fillers and plasticizers), the foaming properties (e.g. antifoaming agents), the lubricating properties (waxes), UV reactivity and stability (photosensitizers and photostabilizers) and adhesion properties, etc. Additives described herein may be present in the coating compositions described herein in amounts and in forms known in the art, including in the form of so-called nano-materials where at least one of the dimensions of the particles is in the range of 1 to 1000 nm.

[0127] The first and second radiation curable coating compositions described herein may be independently prepared by dispersing or mixing the platelet-shaped magnetic or magnetizable pigment particles described herein and the one or more additives when present in the presence of the binder material described herein, thus forming liquid compositions. When present, the one or more photoinitiators may be added to the composition either during the dispersing or mixing step of all other ingredients or may be added at a later stage, i.e. after the formation of the liquid coating composition.

[0128] The process for producing the OEL described herein comprises partially simultaneously with step b) (step b') and/or b'') and/or optional step b''') or subsequently to step b) (step b') and/or b'') and/or optional step b'''), preferably partially simultaneously, a curing step c) (step c') and/or c'') and/or optional step c''') of the radiation curable coating compositions. The step of curing the coating compositions allows the platelet-shaped magnetic or magnetizable pigment particles to be fixed in their adopted positions and orientations in a desired pattern to form the OEL, thereby transforming the radiation curable coating composition to a second state. However, the time from the end of orientation step b) (step b') and/or b'') and/or optional step b''') to the beginning of the curing step c) (step c') and/or c'') and/or optional step c''') is preferably relatively short in order to avoid any de-orientation and loss of information. Typically, the time between the end of step b) (step b') and/or b'') and/or optional step b''') and the beginning of step c) (step c') and/or c'') and/or optional step c''') is less than 1 minute, preferably less than 20 seconds, further preferably less than 5 seconds. It is particularly preferable that there is essentially no time gap between the end of the orientation step b) (step b') and/or b'') and the beginning of the curing step c) (step c') and/or c'') and/or optional step c'''), i.e. that step c) follows immediately after step b) or already starts while step b) is still in progress (partially simultaneously). By "partially simultaneously", it is meant that both steps are partly performed simultaneously, i.e. the times of performing each of the steps partially overlap. In the context described herein, when curing is performed partially simultaneously with the step c), it must be

understood that curing becomes effective after the orientation so that the platelet-shaped magnetic or magnetizable pigment particles orient before the complete or partial curing of the OEL. As mentioned herein, the curing step c)) (step c') and/or c'') and/or optional step c''') may be performed by using different means or processes depending on the binder material comprised in the coating composition that also comprises the platelet-shaped magnetic or magnetizable pigment particles.

[0129] The curing steps generally may be any step that increases the viscosity of the radiation curable coating composition such that a substantially solid material adhering to the substrate is formed. The curing steps may involve a physical process based on the evaporation of a volatile component, such as a solvent, and/or water evaporation (i.e. physical drying). Herein, hot air, infrared or a combination of hot air and infrared may be used. Alternatively, the curing steps may include a chemical reaction, such as a curing, polymerizing or cross-linking of the binder and optional initiator compounds and/or optional cross-linking compounds comprised in the radiation curable coating composition. Such a chemical reaction may be initiated by heat or IR irradiation as outlined above for the physical hardening processes, but may preferably include the initiation of a chemical reaction by a radiation mechanism including without limitation Ultra-violet-Visible light radiation curing (hereafter referred as UV-Vis curing) and electronic beam radiation curing (E-beam curing); oxypolymerization (oxidative reticulation, typically induced by a joint action of oxygen and one or more catalysts preferably selected from the group consisting of cobalt-containing catalysts, vanadium-containing catalysts, zirconium-containing catalysts, bismuth-containing catalysts and manganese-containing catalysts); cross-linking reactions or any combination thereof.

[0130] Radiation curing is particularly preferred, and UV-Vis light radiation curing is even more preferred, since these technologies advantageously lead to very fast curing processes and hence drastically decrease the preparation time of any article comprising the OEL described herein. Moreover, radiation curing has the advantage of producing an almost instantaneous increase in viscosity of the coating composition after exposure to the curing radiation, thus minimizing any further movement of the particles. In consequence, any loss of orientation after the magnetic orientation step can essentially be avoided. Particularly preferred is radiation-curing by photo-polymerization, under the influence of actinic light having a wavelength component in the UV or blue part of the electromagnetic spectrum (typically 200 nm to 650 nm; more preferably 200 nm to 420 nm). Suitable curing units (x50', x50'' and optional x50''') for the curing steps (step c') and step c'') and/or optional step c''') may comprise a high-power light-emitting-diode (LED) lamp, or an arc discharge lamp, such as a medium-pressure mercury arc (MPMA) or a metal-vapor arc lamp, as the source of the actinic radiation. On the contrary to medium-pressure mercury lamps that have emission bands in the UV-A, UV-B and UV-C regions of the electromagnetic spectrum, UV-LED lamps emit radiation in the UV-A region and/or visible (Vis) region, e.g. in the range from about 350 nm to about 470 nm. Moreover, current UV-LED and Vis-LED lamps emit quasi monochromatic radiation, i.e. only emit at one wavelength, such as 365 nm, 385 nm, 395 nm, 405 nm or 450 nm. Preferably, at least one of the steps c') and c'') and optional c'''), more preferably steps c') and c'') and optional step c'''), described herein are carried out by exposing the first coating layer (x20') and the second coating layer (x20'') and the optional third coating layer (x20'''), respectively, to UV light with the LED curing unit (x50', x50'', x50'''), preferably to one or more wavelengths between about 355 nm and about 415 nm, more preferably by exposure to UV light at 365 nm and/or 385 nm and/or 395 nm, emitted from the LED curing unit (x50', x50'', x50''')

[0131] The process described herein may further comprise a step of customization during the first set of steps so as to produce OELs comprising a first motif further exhibiting one or more indicia, wherein said step of customization occurs after step b') and prior to step c'). The customization steps are preferably carried out by independently applying a liquid coating composition on top of the coating layer which is still in a wet state (a wet-on-wet process), said application being carried out contactless fluid microdispensing process such as disclosed in WO 2021/259527 A1.

[0132] The present invention provides the processes to produce the OELs described herein on the substrate (x10) described herein. The substrate described herein is preferably selected from the group consisting of papers or other fibrous materials (including woven and non-woven fibrous materials), such as cellulose, paper-containing materials, glasses, metals, ceramics, plastics and polymers, metalized plastics or polymers, at least partially opacified plastics or polymers, composite materials and mixtures or combinations of two or more thereof. Typical paper, paper-like or other fibrous materials are made from a variety of fibers including without limitation abaca, cotton, linen, wood pulp, and blends thereof. As is well known to those skilled in the art, cotton and cotton/linen blends are preferred for banknotes, while wood pulp is commonly used in non-banknote security documents. Typical examples of plastics and polymers include polyolefins such as polyethylene (PE) and polypropylene (PP) including biaxially oriented polypropylene (BOPP), polyamides, polyesters such as polyethylene terephthalate (PET), poly(1,4-butylene terephthalate) (PBT), polyethylene 2,6-naphthoate (PEN) and polyvinylchlorides (PVC). Spunbond olefin fibers such as those sold under the trademark Tyvek® may also be used as substrate. Typical examples of metalized plastics or polymers include the plastic or polymer materials described hereabove having a metal disposed continuously or discontinuously on their surface. Typical examples of metals include without limitation aluminum (Al), chromium (Cr), copper (Cu), gold (Au), silver (Ag), alloys thereof and combinations of two or more of the aforementioned metals. The metallization of the plastic or polymer materials described hereabove may be done by an electrodeposition process, a high-vacuum coating process or by a sputtering process.

Opacified polymers have been developed with the aim of mimicking the appearance and some properties of conventional paper-based substrates for security document and consist of polymeric transparent substrates which are surface treated typically on one or on both of their sides with opacifying layers so as to form opacified polymer based substrates. Typical examples of composite materials include without limitation multilayer structures or laminates of paper and at least one plastic or polymer material such as those described hereabove as well as plastic and/or polymer fibers incorporated in a paper-like or fibrous material such as those described hereabove. Of course, the substrate can comprise further additives that are known to the skilled person, such as fillers, sizing agents, whiteners, processing aids, reinforcing or wet strengthening agents, etc. When the OELs produced according to the present invention are used for decorative or cosmetic purposes including for example fingernail lacquers, said OEL may be produced on other type of substrates including nails, artificial nails or other parts of an animal or human being.

[0133] According to one embodiment, the substrate (x10) described herein is a transparent substrate preferably selected from the group consisting of transparent polyolefins (such as polyethylene (PE) and polypropylene (PP) including biaxially oriented polypropylene (BOPP)), transparent polyamides, transparent polyesters (such as polyethylene terephthalate) (PET), poly(1,4-butylene terephthalate) (PBT), polyethylene 2,6-naphthoate) (PEN) and transparent polyvinylchlorides (PVC), more preferably biaxially oriented polypropylene; or a partially opacified substrate, in particular an at least partially opacified transparent polymer, preferably selected from the group consisting of transparent polyolefins (such as polyethylene (PE) and polypropylene (PP) including biaxially oriented polypropylene (BOPP)), transparent polyamides, transparent polyesters (such as polyethylene terephthalate) (PET), poly(1,4-butylene terephthalate) (PBT), polyethylene 2,6-naphthoate) (PEN) and transparent polyvinylchlorides (PVC), more preferably biaxially oriented polypropylene. According to one embodiment, the OELs described herein are present on a banknote and are present on a transparent substrate such as those described herein and preferably in the form of a window or a foil or on an at least partially opacified substrate such as those described herein, preferably in the non-opacified areas, preferably in the form of a non-opacified area in the form of a window or a foil.

[0134] The substrates (x10) described herein may be in the form of webs, sheets, thread reels, film reels, labels of the roll or label stocks, preferably sheets.

[0135] Should the OEL produced according to the present invention be on a security document, and with the aim of further increasing the security level and the resistance against counterfeiting and illegal reproduction of said security document, the substrate may comprise printed, coated, or laser-marked or laser-perforated indicia, watermarks, security threads, fibers, planchettes, luminescent compounds, windows, foils, decals and combinations of two or more thereof. With the same aim of further increasing the security level and the resistance against counterfeiting and illegal reproduction of security documents, the substrate may comprise one or more marker substances or taggants and/or machine readable substances. According to one embodiment, the substrate (x10) comprises a printed pattern, preferably an offset printed pattern, wherein at least one of the radiation curable coating compositions of steps a') and a'') and optional a''') is applied at least partially on top of said printed pattern and the process described herein comprises a step of printing an ink on the substrate (x10) described herein, wherein said step occurs prior to step a') and step a'') and optional step a''') described herein, as the case may be.

[0136] If desired, a primer layer may be applied to the substrate (x10) prior to the step a') or prior to step a'') or prior to the optional step a'''). This may enhance the quality of the OEL described herein or promote adhesion. Examples of such primer layers may be found in WO 2010/058026 A2.

[0137] With the aim of increasing the durability through soiling or chemical resistance and cleanliness and thus the circulation lifetime of an article, a security document or a decorative element or object comprising the OEL obtained by the process described herein, or with the aim of modifying their aesthetical appearance (e.g. optical gloss), one or more protective layers may be applied on top of the OEL. When present, the one or more protective layers are typically made of protective varnishes. These may be transparent or slightly colored or tinted and may be more or less glossy. Protective varnishes may be radiation curable compositions, thermal drying compositions or any combination thereof. Preferably, the one or more protective layers are radiation curable compositions, more preferable UV-Vis curable compositions. The protective layers are typically applied after the formation of the OEL.

[0138] The process described herein may further comprise a step of embossing the OEL described herein using for example an embossing dye or an intaglio printing plate as disclosed in WO 2012/025206 A2 and WO 2019/233624 A1,

[0139] The OEL described herein may be used in combination with holograms, microlenses and/or micromirrors as describe in WO 2020/244805 A1, EP 3 254 863 A1, US 2008/0160226, US 2005/0180020 and EP 2 284 017 A1, said holograms, microlenses and/or micromirrors being applied at a position spaced apart from the OEL or least partially on top or below the OEL.

[0140] The present invention further provides optical effect layers (OELs) produced by the process according to the present invention.

[0141] According to one embodiment shown in the Examples E4-E5, the OEL comprises the first motif comprising platelet-shaped magnetic or magnetizable pigment particles oriented according to the first magnetic pattern described herein, the second motif comprising the platelet-shaped magnetic or magnetizable pigment particles oriented according

to the second magnetic pattern described herein, and a third motif comprising the platelet-shaped magnetic or magnetizable pigment particles oriented according to the third magnetic pattern described herein, wherein the first and second patterns are different from each other, the third and second patterns are the same or different from each other, wherein the second motif is at least partially adjacent to and in proper register with the first motif and wherein the third motif is at least partially adjacent to and in proper register with the first motif and/or at least partially adjacent to and in proper register with the second motif. Also described herein are processes for producing OELs with the three motifs described herein, wherein said processes comprise the first set of steps (S1) a'), b') and c') described herein, the second set of steps (S2) a''), b'') and c'') described herein and a third set of steps (S3) a'''), b''') and c''') described herein, said third set of steps (S3), in particular said step a''') being carried out subsequently to and continuously with step c'').

[0142] According to one embodiment shown in Fig. 1C, the process described herein comprises the two set of steps (S1 and S2) described herein and further comprises a third set of steps (S3) so as to produce an optical effect layer (OEL) comprising the first motif comprising magnetically oriented platelet-shaped magnetic or magnetizable pigment particles oriented according to the first magnetic pattern described herein, the second motif comprising magnetically oriented platelet-shaped magnetic or magnetizable pigment particles oriented according to the second magnetic pattern described herein and a third motif comprising magnetically oriented platelet-shaped magnetic or magnetizable pigment particles oriented according to a third magnetic pattern, wherein the substrate (x10) comprises the first coating layer (x20') and the second coating layer (x20'') being present on the same side of the substrate (x10), said third set of steps (S3) comprising:

a''') applying onto the side of the substrate (x10) lacking the first coating layer (x20') and lacking the second coating layer (x20'') in register a third radiation curable coating composition, preferably a third UV-Vis-curable curable coating composition, comprising platelet-shaped magnetic or magnetizable pigment particles so as to form a third coating layer (x20'''), said coating composition being in a first state, and at least a part of the third coating layer (x20''') being adjacent to at least a part of the first coating layer (x20') and/or adjacent to at least a part of the second coating layer (x20'') (see for example Fig. 1C and Fig. 9);

b''') exposing the third radiation curable coating composition of step a''') to a magnetic field of a magnetic assembly (x30'') so as to bi-axially orient at least a part of the platelet-shaped magnetic or magnetizable pigment particles; and c''') at least partially curing the second radiation curable coating composition of step b''') to a second state so as to fix the platelet-shaped magnetic or magnetizable pigment particles in their adopted positions and orientations and so as to produce the third motif.

[0143] According to one embodiment, the process described herein comprises the two sets of steps (S1 and S2) described herein and further comprises a third set of steps (S3) so as to produce an optical effect layer (OEL) comprising the first motif comprising magnetically oriented platelet-shaped magnetic or magnetizable pigment particles oriented according to the first magnetic pattern described herein, the second motif comprising magnetically oriented platelet-shaped magnetic or magnetizable pigment particles oriented according to the second magnetic pattern described herein and a third motif comprising magnetically oriented platelet-shaped magnetic or magnetizable pigment particles oriented according to a third magnetic pattern, wherein the first coating layer (x20') is present on a first side of the substrate (x10) and the second coating layer (x20'') is present on a second side (i.e. the opposite side) of the substrate (x10), said third set of steps (S3) comprising:

a''') applying onto the side of the substrate (x10) comprising the first coating layer (x20') in a cured state and lacking the second coating layer (x20'') in register a third radiation curable coating composition, preferably a third UV-Vis-curable curable coating composition, comprising platelet-shaped magnetic or magnetizable pigment particles so as to form a third coating layer (x20'''), said coating composition being in a first state, and at least a part of the third coating layer (x20''') being adjacent to at least a part of the first coating layer (x20') and/or adjacent to at least a part of the second coating layer (x20'');

b''') exposing the third radiation curable coating composition of step a''') to a magnetic field of a magnetic assembly (x30'') so as to bi-axially orient at least a part of the platelet-shaped magnetic or magnetizable pigment particles; and c''') at least partially curing the third radiation curable coating composition of step b''') to a second state so as to fix the platelet-shaped magnetic or magnetizable pigment particles in their adopted positions and orientations as described herein and so as to produce the third motif.

[0144] According to one embodiment, the process described herein comprises the two sets of steps (S1 and S2) described herein and further comprises a third set of steps (S3) so as to produce an optical effect layer (OEL) comprising the first motif comprising magnetically oriented platelet-shaped magnetic or magnetizable pigment particles oriented according to the first magnetic pattern described herein, the second motif comprising magnetically oriented platelet-shaped magnetic or magnetizable pigment particles oriented according to the second magnetic pattern described herein

and a third motif comprising magnetically oriented platelet-shaped magnetic or magnetizable pigment particles oriented according to a third magnetic pattern, wherein the first coating layer (x20') is present on a first side of the substrate (x10) and the second coating layer (x20'') is present on a second side (i.e. the opposite side), of the substrate (x10), said third set of steps (S3) comprising:

a''') applying onto the side of the substrate (x10) comprising the second coating layer (x20'') in a cured state and lacking the first coating layer (x20') in register a third radiation curable coating composition, preferably a third UV-Vis-curable curable coating composition, comprising platelet-shaped magnetic or magnetizable pigment particles so as to form a third coating layer (x20'''), said coating composition being in a first state, and at least a part of the third coating layer (x20''') being adjacent to at least a part of the first coating layer (x20') and/or adjacent to at least a part of the second coating layer (x20'');

b''') exposing the third radiation curable coating composition of step a''') to a magnetic field of a magnetic assembly (x30''') so as to bi-axially orient at least a part of the platelet-shaped magnetic or magnetizable pigment particles; and c''') at least partially curing the third radiation curable coating composition of step b''') to a second state so as to fix the platelet-shaped magnetic or magnetizable pigment particles in their adopted positions and orientations as described herein and so as to produce the third motif.

[0145] According to one embodiment, the process described herein comprises the two sets of steps (S1 and S2) described herein and further comprises a third set of steps (S3) so as to produce an optical effect layer (OEL) comprising the first motif comprising magnetically oriented platelet-shaped magnetic or magnetizable pigment particles oriented according to the first magnetic pattern described herein, the second motif comprising magnetically oriented platelet-shaped magnetic or magnetizable pigment particles oriented according to the second magnetic pattern described herein and a third motif comprising magnetically oriented platelet-shaped magnetic or magnetizable pigment particles oriented according to a third magnetic pattern, wherein the substrate (x10) comprises the first coating layer (x20') and the second coating layer (x20'') being present on the same side of the substrate (x10), said third set of steps (S3) comprising:

a''') applying onto the side of the substrate (x10) comprising the first coating layer (x20') and the second coating layer (x20'') in a cured state in register a third radiation curable coating composition, preferably a third UV-Vis-curable curable coating composition, comprising platelet-shaped magnetic or magnetizable pigment particles so as to form a third coating layer (x20'''), said coating composition being in a first state, and at least a part of the third coating layer (x20''') being adjacent to at least a part of the first coating layer (x20') and/or adjacent to at least a part of the second coating layer (x20'');

b''') exposing the third radiation curable coating composition of step a''') to a magnetic field of a magnetic assembly (x30''') so as to bi-axially orient at least a part of the platelet-shaped magnetic or magnetizable pigment particles; and c''') at least partially curing the third radiation curable coating composition of step b''') to a second state so as to fix the platelet-shaped magnetic or magnetizable pigment particles in their adopted positions and orientations as described herein and so as to produce the third motif.

[0146] The OEL described herein may be provided directly on a substrate (x10) on which it shall remain permanently (such as for banknote applications). Alternatively, an OEL may also be provided on a temporary substrate for production purposes, from which the OEL is subsequently removed. This may for example facilitate the production of the OEL, particularly while the binder material is still in its fluid state. Thereafter, after curing the radiation curable compositions for the production of the OEL, the temporary substrate may be removed from said OEL.

[0147] Alternatively, in another embodiment an adhesive layer may be present. Therefore, an adhesive layer may be applied after the curing step of the last set of steps described herein has been completed. Such an article may be attached to all kinds of documents or other articles or items without printing or other processes involving machinery and rather high effort. Alternatively, the substrate described herein comprising the OEL described herein may be in the form of a transfer foil, which can be applied to a document or to an article in a separate transfer step. For this purpose, the substrate is provided with a release coating, on which the OEL is produced as described herein.

[0148] Also described herein are substrates (x10) comprising more than one, i.e. two, three, four, etc. OELs obtained by the process described herein, each of said OELs independently comprising the first and second motifs described herein in the form of the first and second coating layers (x20', x20''). The process for producing more than one OELs on the substrate (x10) described herein may comprises a first set of steps (S1) a'), b') and c') to produce the first motif of a first OEL, a second set of steps (S2) a''), b'') and c'') to produce the second motif of the first OEL, a third set of steps (S3) a'''), b''') and c''') to produce the first motif of the second OEL and a fourth set of steps (S4) a''''), b'''')) and c'''')) to produce the second motif of the second OEL. Alternatively, the process for producing more than one OELs on the substrate (x10) described herein may comprise a first set of steps (S1) a'), b') and c') to produce the first motif of a first OEL, a second set of steps (S2) a''), b'') and c'') to produce the first motif of the second OEL, a third set of steps (S3) a'''), b''') and c''') to produce the second motif of the second OEL, a fourth set of steps (S4) a''''), b'''')) and c'''')) to produce the first motif of a third OEL, a fifth set of steps (S5) a'''''), b''''')) and c''''')) to produce the second motif of the third OEL, and so on.

), b''') and c''') to produce the second motif of the first OEL and a fourth set of steps (S4) a''''), b'''')) and c'''')) to produce the second motif of the second OEL.

[0149] Also described herein are articles, in particular security documents, decorative elements or objects, comprising the OEL produced according to the present invention. The articles, in particular security documents, decorative elements

or objects, may comprise more than ones (for example two, three, etc.) OELs produced according to the present invention.

[0150] As mentioned hereabove, the OEL produced according to the present invention may be used for decorative purposes as well as for protecting and authenticating a security document.

[0151] Typical examples of decorative elements or objects include without limitation luxury goods, cosmetic packaging, automotive parts, electronic/electrical appliances, furniture and fingernail articles.

[0152] Security documents include without limitation value documents and value commercial goods. Typical examples of value documents include without limitation banknotes, deeds, tickets, checks, vouchers, fiscal stamps and tax labels, agreements and the like, identity documents such as passports, identity cards, visas, driving licenses, bank cards, credit cards, transactions cards, access documents or cards, entrance tickets, public transportation tickets or titles and the like, preferably banknotes, identity documents, right-conferring documents, driving licenses and credit cards. The term "value commercial good" refers to packaging materials, in particular for cosmetic articles, nutraceutical articles, pharmaceutical articles, alcohols, tobacco articles, beverages or foodstuffs, electrical/electronic articles, fabrics or jewelry, i.e. articles that shall be protected against counterfeiting and/or illegal reproduction in order to warrant the content of the packaging like for instance genuine drugs. Examples of these packaging materials include without limitation labels, such as authentication brand labels, tamper evidence labels and seals. It is pointed out that the disclosed substrates, value documents and value commercial goods are given exclusively for exemplifying purposes, without restricting the scope of the invention.

[0153] Alternatively, the OEL may be produced onto an auxiliary substrate such as for example a security thread, security stripe, a foil, a decal, a window or a label and consequently transferred to a security document in a separate step.

[0154] The skilled person can envisage several modifications to the specific embodiments described above without departing from the spirit of the present invention. Such modifications are encompassed by the present invention.

[0155] Further, all documents referred to throughout this specification are hereby incorporated by reference in their entirety as set forth in full herein.

EXAMPLES

[0156] The present invention is now described in more details with reference to non-limiting examples. The Examples below provide more details for the processes according to the present invention and suitable magnetic assemblies for the production of optical effects layers (OELs).

[0157] The OELs obtained by the process of Examples E1-E5 were prepared on a laboratory equipment according to processes comprising two sets of steps (E1-E3) or three sets of steps (E4-E5), wherein

the first orientation step b') of the first set is shown in Fig. 5A to mimic an industrial process comprising a two-steps orientation step shown in Fig. 5B (E1-E5);

wherein the orientation step b'') of the second set is shown in Fig. 7A to mimic an industrial process comprising a one-step orientation step shown in Fig. 7C (for example E1) or shown in Fig. 8A to mimic an industrial process comprising a one-step orientation step shown in Fig. 8C (for examples E2-E5); and

wherein the orientation step b''') of the third set is shown in Fig. 9 to mimic an industrial process comprising a one-step orientation step similar to step b'') shown in Fig. 8C (for examples E4-E5).

[0158] The exact register of the first motif, the second motif and the third motif, when present, (i.e. of the first, second and third cured coating layers (x20', x20'', x20''')) was ensured by using screens comprising, in addition to the motifs to be printed, guiding marks.

[0159] Examples E1-E3 were independently prepared by using the UV-curable screen printing inks of Table 1, wherein the first UV-curable screen printing ink I1 was applied in steps a') on a first side of a transparent substrate (x10) (polymeric BOPP substrate, Guardian™ from CCL) so as to form the first coating layer (x20') and the second UV-curable screen printing ink I1 was applied (step a'')) on the same side of the substrate (x10) and partially on top and in directed contact with the first coating layer (x20') (see Figs 1A and 7).

[0160] Examples E4-E5 were independently prepared by using the UV-curable screen printing inks of Table 1, wherein the first UV-curable screen printing ink I1 was applied in steps a') on a first side of the transparent substrate (x10) so as to form the first coating layer (x20'); the second UV-curable screen printing ink I1 was applied (step a'')) in register with the first coating layer (x20') on the same side of the substrate (x10) and partially on top of and in directed contact with the first coating layer (x20'); and the third UV-curable screen printing ink I2 was applied (step a'')) in register with the first and second coating layers (x20', x20'') on the opposite side of the substrate (x10) (i.e. the side of the substrate (x10)

lacking the first and second coating layers (x20' and x20") and on top of and in indirect contact (through the substrate (x10) with the first coating layer (x20') and the second coating layer (x20") (see Figs 1C and 9).

[0161] The first UV-curable screen printing ink was applied (step a')) by hand screen printing using a first T90 screen (x40') so as to form the first coating layer (x20') having a thickness of about 20 μm and having a shape as shown in Tables 2.

[0162] The second UV-curable screen printing ink was applied (step a'')) on the first side of the substrate (x10) in exact register with the first coating layer (x20') applied in step a'), said application being carried out by hand screen printing using a second T90 screen (x40'') so as to form the second coating layer (x20'') having a thickness of about 20 μm and having a shape as shown in Tables 2.

[0163] The third UV-curable screen printing ink was applied (step a''')) on the second side of the substrate (x10) (i.e. the side of the substrate (x10) lacking the first and second coating layers (x20' and x20'') in exact register with the first coating layer (x20') applied in step a'') and in exact register with the second coating layer (x20''), said application being carried out by hand screen printing using a third T90 screen (x40''') so as to form the third coating layer (x20''') having a thickness of about 20 μm and having a shape as shown in Tables 2.

Two-steps orientation for the first coating layer/first motif (Fig. 5A, steps b')-c') of Examples E1-E5)

[0164] The substrate (510) carrying the first coating layer (520') was moved (see grey arrow in Fig. 5A) above a static magnetic assembly (530'-a) (step b'-1)) and was subsequently placed on a second magnetic assembly (530'-b), said second magnetic assembly (530'-b) being the magnetic assembly 1130 of Fig. 11. The so-obtained magnetic orientation pattern of the platelet-shaped magnetic pigment particles was then, partially simultaneously with the orientation step b'-2), (i.e. while the substrate (510) carrying the first coating layer (520') was still in the magnetic field of the magnetic assembly (530'-b), fixed by exposing for about 1.5 seconds to UV-curing the layer comprising the pigment particles using a first UV-LED-lamp (550') from Phoseon (Type FireFlex 50 x 75 mm, 395 nm, 8 W/cm²) (step c').

One-step orientation for the second coating layer/second motif applied on the side of the substrate carrying the first coating layer/first motif (Fig. 7A, steps a'')-c'') of Example E1)

[0165] The second UV-curable screen printing ink was applied (step a'')) onto the same side of substrate (710) carrying the first coating layer (720') so as to form the second coating layer (720'') in exact register with said first coating layer (720'). The substrate (710) carrying the first and second coating layers (720' and 720'') was placed above a static magnetic assembly (730'') being the magnetic assembly 1030 of Fig. 10 (step b'')) and moved back and forth ten times at a linear speed of about 1 m/s in the magnetic field generated by said assembly (step b'-1)) with the side of the substrate (710) lacking the first and second coating layers (720' and 720'') facing the static magnetic assembly (730''). The so-obtained magnetic orientation pattern of the platelet-shaped magnetic pigment particles was then, partially simultaneously with the orientation step b''), (i.e. while the substrate (710) carrying the first and second coating layers (720' and 720'') was still in the magnetic field of the magnetic assembly (730''), fixed by exposing for about 1.5 seconds to UV-curing the layer comprising the pigment particles using a second UV-LED-lamp (750'') from Phoseon (Type FireFlex 50 x 75 mm, 395 nm, 8 W/cm²) (step c'')).

One-step orientation for the second coating layer/second motif applied on the side of the substrate carrying the first coating layer/first motif (Fig. 8A, steps a'')-c'') of Examples E2-E5)

[0166] The second UV-curable screen printing ink was applied (step a'')) onto the same side of the substrate (810) carrying the first coating layer (820') so as to form the second coating layer (820'') in exact register with said first coating layer (820'). The substrate (810) carrying the first and second coating layers (820' and 820'') was placed above a spinning magnetic assembly (830'') (step b'')) with the side of the substrate (810) lacking the first and second coating layers (820' and 820'') facing the spinning magnetic assembly (830''). The so-obtained magnetic orientation pattern of the platelet-shaped magnetic pigment particles was then, partially simultaneously with the orientation step b''), (i.e. while the substrate (810) carrying the first and second coating layers (820' and 820'') was still in the magnetic field of the magnetic assembly (830''), fixed by exposing for about 1.5 seconds to UV-curing the layer comprising the pigment particles using a second UV-LED-lamp (850'') from Phoseon (Type FireFlex 50 x 75 mm, 395 nm, 8 W/cm²) (step c'')).

One-step orientation for the third coating layer/third motif applied on the side of the substrate lacking the first and second coating layers (Fig. 9, steps a''')-c''') of Examples E4-E5)

[0167] The substrate carrying the first coating layer (920') and the second coating layer (920'') on the same side was flipped/rotated and the third UV-curable screen printing ink was applied (step a''')) on the side of the substrate lacking the first and second coating layers (920', 920'') so as to form the third coating layer (920''') in exact register with said

first coating layer (920') and in exact register with said second coating layer (920"). The substrate (910) carrying the first, second and third coating layers (920', 920", 920''') was placed above a spinning magnetic assembly (930'') with the side of the substrate (910) comprising the first and second coating layers (920' and 920") in a cured state facing the spinning magnetic assembly (930'''). The so-obtained magnetic orientation pattern of the platelet-shaped magnetic pigment particles was then, partially simultaneously with the orientation step b'''), (i.e. while the substrate (910) carrying the first, second and third coating layers (920', 920", 920''') was still in the magnetic field of the spinning magnetic assembly (930'''), fixed by exposing for about 1.5 seconds to UV-curing the layer comprising the pigment particles using a second UV-LED-lamp (950''') from Phoseon (Type FireFlex 50 x 75 mm, 395 nm, 8 W/cm²) (step c''').

Table 1

	I1	I2
Epoxyacrylate oligomer	28.5%	28.5%
Trimethylolpropane triacrylate monomer	20.6%	20.6%
Tripropyleneglycol diacrylate monomer	20.6%	20.6%
Genorad 16 (Rahn)	1%	1%
Aerosil 200 (Evonik)	1.6%	1.6%
Speedcure TPO-L (Lambson)	2.8%	2.8%
Omnirad 184 (IGM)	2%	2%
Genocure® DETX (Rahn)	0.5%	0.5%
Genocure® EPD (Rahn)	2%	2%
BYK® 371 (BYK)	2%	2%
Tego Foamex N (Evonik)	1.9%	1.9%
7-layer colorshifting magnetic pigment particles (*) (Viavi Solutions)	16.5%	--
7-layer colorshifting magnetic pigment particles (**) / (Viavi Solutions)	--	16.5%
(*) gold-to-green colorshifting magnetic pigment particles having a flake shape (platelet-shaped pigment particles) of diameter d50 of about 11 µm and thickness about 1 µm.		
(**) green-to-blue colorshifting magnetic pigment particles having a flake shape (platelet-shaped pigment particles) of diameter d50 of about 11 µm and thickness about 1 µm.		

Magnetic assembly of Fig. 10

[0168] The magnetic assembly (1030) used to bi-axially orient the pigment particles according to the process of the present invention is disclosed in Fig. 3A of WO 2021/239607 A1. The magnetic assembly (1030) consists of (530'-a) when used in the first step b'-1 of Fig. 5A or (730'') when used in the step of Fig. 7A.

[0169] The magnetic assembly (1030) comprised a) a first set (S1) comprising a first bar dipole magnet (1531-a) and two second bar dipole magnets (1032-a and 1032-d), a second set (S2) comprising a first bar dipole magnet (1031-b) and two second bar dipole magnets (1032-b and 1032-e), a third set (S3) comprising a first bar dipole magnet (1031-c) and two second bar dipole magnets (1032-c and 1032-f), and b) a first pair (P1) of third bar dipole magnets (1033-a and 1033-b) and a second pair (P2) of third bar dipole magnets (1033-c and 1033-f).

[0170] The uppermost surface of the first bar dipole magnet (1031-a, 1031-b and 1031-c) of the first, second and third sets (S1, S2, S3), of the second bar dipole magnets (1032-a to 1032-f) of the first, second and third sets (S1, S2, S3) and of the third bar dipole magnets (1033-a to 1033-d) of the first and second pairs (P1 and P2) were flush with each other.

[0171] The third bar dipole magnet (1033-a) of the first pair (P1) was aligned with the second bar dipole magnet (1032-a) of the first set (S1), with the second bar dipole magnet (1032-b) of the second set (S2), with the third bar dipole magnet (1033-c) of the second pair (P2) and with the second bar dipole magnet (1032-c) of the third set (S3) so as to form a line. The third bar dipole magnet (1033-b) was aligned with the second bar dipole magnet (1032-d) of the first set (S1), with the second bar dipole magnet (1032-e) of the second set (S2), with the third bar dipole magnet (1033-d) of the second pair (P2) and with the second bar dipole magnet (1032-f) of the third set (S3) so as to form a line. For each line described herein, the third bar dipole magnets (1033-a, 1033-b, 1033-c and 1033-d) and the second bar dipole magnets (1032-a to 1032-f) were spaced apart by a third distance (d2) of 2 mm. The first bar dipole magnet (1031-a) of the first

set (S1) and the first bar dipole magnet (1031-b) of the second set (S2), and the first bar dipole magnet (1031-c) of the third set (S3) were spaced apart by a distance (d3) of 24 mm.

[0172] The first bar dipole magnets (1031-a, 1031-b and 1031-c) of the first, second and third sets (S1, S2, S3) had the following dimensions: first length (L1) of 60 mm, first width (L2) of 40 mm and first thickness (L3) of 5 mm. Each of the second bar dipole magnets (1032-a to 1032-f) of the first, second and third set (S1, S2, S3) had the following dimensions: second length (L4) of 40 mm, second width (L5) of 10 mm and second thickness (L6) of 10 mm. Each of the third bar dipole magnets (1033-a to 1033-d) of the first and second pairs (P1, P2) had the following dimensions: third length (L7) of 20 mm, third width (L8) of 10 mm and third thickness (L9) of 10 mm.

[0173] The first bar dipole magnet (1031-a) of the first set (S1) and the second bar dipole magnets (1032-a and 1032-d) of the first set (S1) were aligned to form a column; and the first bar dipole magnet (1031-b) of the second set (S2) and the second bar dipole magnets (1032-b and 1032-e) of the second set (S2) were aligned to form a column; and the first bar dipole magnet (1031-c) of the third set (S3) and the second bar dipole magnets (1032-c and 1032-f) of the third set (S3) were aligned to form a column. For each set (S1, S2, S3) and each column described herein, the first bar dipole magnets (1031-a, 1031-b and 1031-c) and the two second bar dipole magnets (1032-a and 1032-d; 1032-b and 1032-e; and 1032-c and 1032-f, respectively) were spaced apart by a second distance (d1) of 2 mm.

[0174] The first bar dipole magnets (1031-a, 1031-b and 1031-c) of the first, second and third sets (S1, S2, S3) had their magnetic axis oriented to be substantially parallel to the substrate (1010) and substantially parallel to the substrate (1010), wherein the first bar dipole magnet (1031-a) of the first set (S1) had its magnetic direction opposite to the magnetic direction of the first bar dipole magnet (1031-b) of the second set (S2), and the first bar dipole magnet (1031-b) of the second set (S2) had its magnetic direction opposite to the magnetic direction of the first bar dipole magnet (1031-c) of the third set (S3). The first bar dipole magnet (1031-a) of the first set (S1) and first bar dipole magnet (1031-b) of the second set (S2), as well as the first bar dipole magnet (1031-b) of the second set (S2) and the first bar dipole magnet (1031-c) of the third set (S3), were spaced apart by a first distance (d3) of 24 mm (corresponding to the sum of the third length (L7) and the two third distances (d2)).

[0175] The two second bar dipole magnets (1032-a to 1032-f) of the first, second and third set (S1, S2, S3) had their magnetic axis oriented to be substantially perpendicular to the substrate (1010) surface. The South pole of the second bar dipole magnet (1032-a) of the first set (S1), the South pole of the second bar dipole magnet (1032-e) of the second set (S2) and the South pole of the second bar dipole magnet (1032-c) of the third set (S3) pointed towards the substrate (1010). The North pole of the second bar dipole magnet (1032-d) of the first set (S1), the North pole of the second bar dipole magnet (1032-b) of the second set (S2) and the North pole of the second bar dipole magnet (1032-f) of the third set (S3) pointed towards the substrate (1010). The North pole of the first bar dipole magnet (1031-a) of the first set (S1) pointed towards the second bar dipole magnet (1032-d) of the first set (S1), the North pole of the second bar dipole magnet (1031-b) of the second set (S2) pointed towards the first bar dipole magnet (1032-b) of the second set (S2) and the North pole of the first bar dipole magnet (1031-c) of the third set (S3) pointed towards the second bar dipole magnet (1032-f) of the third set (S3). The South pole of the third bar dipole magnet (1033-a) of the first pair (P1) pointed towards the second bar dipole magnet (1032-a) of the first set (S1), said second bar dipole magnet (1032-a) having its South pole pointing towards the substrate (1010); the South pole of the third bar dipole magnet (1033-d) of the second pair (P1) pointed towards the second bar dipole magnet (1032-e) of the second set (S2), said second bar dipole magnet (1032-e) having its South pole pointing towards the substrate (1010); the North pole of the third bar dipole magnet (1033-b) of the first pair (P1) pointed towards the second bar dipole magnet (1032-d) of the first set (S1), said second bar dipole magnet (1032-d) having its North pole pointing towards the substrate (1010); and the North pole of the third bar dipole magnet (1033-c) of the second pair (P2) pointed towards the second bar dipole magnet (1032-b) of the second set (S2), said second bar dipole magnet (1032-b) having its North pole pointing towards the substrate (1010).

[0176] The first bar dipole magnets (1031-a, 1031-b and 1031-c) of the first, second and third sets (S1, S2, S3) and the second bar dipole magnets (1032-a to 1032-f) of the first, second and third sets (S1, S2, S3) were made of NdFeB N42; the third bar dipole magnets (1033-a, 1033-b, 1033-c and 1033-d) of the first and second pairs (P1, P2) were made of NdFeB N48. All the magnets (1031-a to 1031-c, 1032-a to 1032-f and 1033-a to 1033-d) were embedded in a non-magnetic supporting matrix (not shown) made of POM having the following dimensions: 200 mm x 120 mm x 12 mm.

Magnetic assembly of Fig. 11

[0177] The magnetic assembly (1130) used to re-orient the pigment particles according to the process of the present invention is shown in Fig. 11. The magnetic assembly (1130) consists of (530'-b) when used in the second step b'-2) of Fig. 5A. The magnetic assembly (1130) comprised a bar dipole magnet (1130-1) and a holding case (1170). The bar dipole magnet (1130-1) had a length and a width of about 30 mm and a thickness of about 8.5 mm. The North-South magnetic axis of the bar dipole magnet (1130-1) was parallel to the substrate (1110) surface, parallel to its length (L1) and parallel to the machine feed direction (shown by the arrow in Fig. 11). The bar dipole magnet (1130-b1) was made of NdFeB BMnPi 80/48.

[0178] The holding case (1170) was made of a hollow top part with a curved surface and a bottom lid. The hollow top part had a length of about 40 mm, a width of about 40 mm, a thickness of about 15.1 mm and was made of PPS. The bottom lid had a length of about 35 mm, a width of about 35 mm, a thickness of about 3 mm and was made of POM. The curved surface was suitable to match the surface of a rotating magnetic cylinder of an industrial printing press. The hollow top part was suitable for receiving the bar dipole magnet (1130-1).

[0179] The distance (h) between the top surface of the bar dipole magnet (1130-1) and the surface of the bottom substrate (1110) was about 3.35 mm.

Magnetic assembly of Fig. 12

[0180] The magnetic assembly (1230) was a spinning magnet similar to the assembly disclosed in Fig. 1 of WO 2018/151547 A1. The magnetic assembly (1230) consists of (830") when used in the step b") of Fig. 8A and consists of (930") when used in the step b") of Fig. 9. The magnetic assembly (1230) comprised:

- i) a holder (1a) (external dimensions: 60 mm x 40 mm x 25 mm) made of aluminum, comprising a rectangular recess (40 mm x 40 mm x 12.5 mm) to receive a "H"-shaped casing (4) and a lid (8), and comprising a square cavity (36.5 mm x 36.5 mm x 6 mm) to receive a magnetic-field-guiding stator core (1c);
- ii) a magnetic-field-guiding stator core (1c) (36 mm x 36 mm x 5 mm; see details in Fig. 3A-B of WO 2018/151547 A1) was milled out of pure iron (Armco) and insulated with a layer of urethane lacquer dried at 80°C for two hours. The magnetic-field-guiding stator core (1c) comprised n (n = 6) annular winding slots (external diameter = 10 mm, internal diameter = 5 mm, depth = 4 mm) disposed in a circle (diameter = 25 mm) and a central hole for mounting purposes. N (n = 6) 120 turns magnet-wire coils (1b) of enameled 0.20 mm self-bonding copper wire (POLYSOL 155 1 x 02 MM HG from Distrelec AG) were wound and fixed to a self-standing condition by a hot air treatment for about two minutes at 250°C and inserted into the n (n = 6) winding slots. The magnet-wire coils (1b) were wired together such as to form a 3-phase Y-scheme stator winding (u, v, w, u', v, w'), wherein each two opposite magnet-wire coils (u, u'), (v, v') (w, w') were electrically connected together such as to produce the same magnetic polarity at diametrically opposed locations. The stator winding was connected via 4 wires (U,V,W,GND) to a motor driver described hereabove;
- iii) a sensorless BLDC motor driver running at 12V DC power (DRV11873EVM, from Texas Instruments);
- iv) a winding protection plate (7) (36 mm x 36 mm x 0.5 mm) made of titanium, comprising a central mounting hole (10 mm diameter) and disposed on top of the magnetic-field-guiding stator core (1c), protecting the magnet-wire coils (1b) and the magnetic-field-guiding stator core (1c);
- v) a single-piece "H"-shaped casing (4) (see Fig. 4A-B of WO 2018/151547 A1) (30 mm x 30 mm x 12.5 mm) made of titanium and having four corners pillars (height = 12.5 mm, width = 10 mm). The "H"-shaped casing (4) comprised a first and a second cavity delimited by a horizontal middle-plate having a thickness of 2 mm and being located at 7 mm from the top surface and 3.5 mm from the bottom surface of the "H"-shaped casing (4). The "H"-shaped casing (4) comprised a central circular hole (diameter = 10 mm) for receiving a ceramic ball bearing (3c) (external diameter = 10 mm, internal diameter = 5 mm, height = 3 mm) which was fixed with epoxy glue in this hole;
- vi) a rotor protection plate (2) (30 mm x 30 mm x 0.5 mm) made of titanium, for closing the first cavity of the "H"-shaped casing (4);
- vii) a rotor disc (3b) (see Fig. 2A-B of WO 2018/151547 A1) (diameter = 30 mm, thickness 2 mm) made of iron (Armco) and comprising a central hub or protrusion with a M3-threaded hole (as illustrated in Fig 2A of WO 2018/151547 A1) on its upper surface; the rotor disc (3b) comprised on its lower surface, m (m = 8) cavities (diameter = 7 mm, depth = 1.2 mm), wherein m (m = 8) permanent magnet poles (NdFeB N45 disc-shaped axially magnetized dipole magnets (3a) (diameter = 6 mm, thickness = 1 mm)) were glued with alternating North and South poles, yielding an octupolar NSNSNSNS circular lower face of the rotor disc (3b). The rotor disc (3b) was inserted into the first cavity of the "H"-shaped casing (4), with the hub or protrusion protruding through the ceramic ball bearing (3c);
- viii) a disc-shaped magnet support (6) support with a 3 mm mounting hole (diameter = 30 mm, thickness = 2 mm) made of aluminum and fixed with an M3 screw to the hub or protrusion of the rotor disc (3b);
- ix) a permanent magnet assembly (5) being a diametrically magnetized NdFeB N40 disc-shaped dipole magnet (diameter = 25 mm, thickness = 2 mm) and glued onto the disc-shaped magnet support (6); and
- x) a lid (8) (40 mm x 40 mm x 15 mm) made of PPS (polyphenylene sulfide), fitted into the rectangular recess of the holder (A) and comprising a recess (30 mm x 30 mm x 13 mm) to accommodate the "H"-shaped casing (4).

[0181] The magnetic gap (G) given by the distance between the topmost surface of the stator (1b + 1c), i.e. the top surface of the magnetic-field-guiding stator core (1c), and the lowest surface of the rotor, was about 2.0 mm, comprising noteworthy the combined thicknesses of the winding protection plate (7) and the titanium protection plate (2) (2 x 0.5 mm) and a about 1 mm free air gap between the lower surface of the rotor and the upper surface rotor protection plate (2).

[0182] The permanent magnet assembly (5) was used at a spinning rate of about 200 rpm for about 2 seconds during the orientation step.

[0183] The distance between the top surface of the permanent magnet assembly (5) and the bottom surface of the substrate (1210) was about 3 mm.

Magnetic assembly of Fig. 13

[0184] The magnetic assembly (1330) was a spinning magnet similar to the assembly disclosed in Fig. 1 of WO 2018/151547 A1. The magnetic assembly (1330) consists of (830") when used in the step b") of Fig. 8A and consists of (930") when used in the step b'") of Fig. 9. The magnetic assembly (1330) was the same as the magnetic assembly (1230) shown in Fig. 12 except that the permanent magnet assembly (5) comprised a diametrically magnetized ring-shaped dipole magnet (5-1) made of NdFeB N40 and having an external diameter of about 25 mm, an internal diameter of about 14 mm and a thickness of about 2 mm and a diametrically magnetized disc-shaped dipole magnet (5-2) made of NdFeB N40 and having a diameter of about 25 mm and a thickness of about 2 mm. The ring-shaped dipole magnet (5-1) was disposed directly on top of the disc-shaped dipole magnet (5-2) and was centrally aligned with the disc-shaped dipole magnet (5-1). The assembly (1330) was used at a spinning rate of about 200 rpm for about 2 seconds during the orientation step.

[0185] The distance between the top surface of the ring-shaped dipole magnet (5-1) surface and the top surface of the substrate (1310) was about 4.5 mm.

Table 2A

	Ink 1	step b')	Ink 2	step b")
E1	 recto	Two steps (Fig. 5A): b'-1) pre-alignment with magnetic assembly 1030 of Fig. 10 b'-2) re-orientation with magnetic assembly 1130 of Fig. 11	 recto	single step (Fig. 7A): b") orientation with magnetic assembly 1030 of Fig. 10
E2	 recto	Two steps (Fig. 5A): b'-1) pre-alignment with magnetic assembly 1030 of Fig. 10 b'-2) re-orientation with magnetic assembly 1130 of Fig. 11	 recto	single step (Fig. 8A): b") orientation with magnetic assembly 1230 of Fig. 12
E3	 recto	Two steps (Fig. 5A): b'-1) pre-alignment with magnetic assembly 1030 of Fig. 10 b'-2) re-orientation with magnetic assembly 1130 of Fig. 11	 recto	single step (Fig. 8A): b") orientation with magnetic assembly 1330 of Fig. 13

Table 2B

E4		E5	
 recto	Two steps (Fig. 5A): b'-1) pre-alignment with magnetic assembly 1030 of Fig. 10 b'-2) re-orientation with magnetic assembly 1130 of Fig. 11	 recto	Two steps (Fig. 5A): b'-1) pre-alignment with magnetic assembly 1030 of Fig. 10 b'-2) re-orientation with magnetic assembly 1130 of Fig. 11

(continued)

E4			E5	
5 11  recto	single step (Fig. 8A): b'') orientation with magnetic assembly 1230 of Fig. 12		11  recto	single step (Fig. 8A): b'') orientation with magnetic assembly 1330 of Fig. 13
10 12  verso	single step (Fig. 9): b''') orientation with magnetic assembly 1230 of Fig. 12		12  verso	single step (Fig. 9): b''') orientation with magnetic assembly 1330 of Fig. 13

[0186] The OEL, i.e. the combination of the first motif, second motif and third motif, when present, shown in Tables 2 had the following dimensions: length of about 25 mm and height of about 20 mm.

[0187] The OEL of example E1 provided, when observed from the side of the substrate carrying the first and second coating layers, a highly reflective image of a turtle with a dynamic effect in the form of a rolling bar, said dynamic effect being particularly visible within the head and legs areas of the turtle, which was moving in a vertical direction when the substrate was tilted around a horizontal axis.

[0188] The OELs of examples E2-E3, when observed from the side of the substrate carrying the first and second coating layers, provided a highly reflective image of a turtle with a dynamic effect in the form of a rolling bar, said dynamic effect being particularly visible within the head and legs areas of said turtle, and a particularly highly reflective shell area of said turtle with a shimmering spot dynamic effect. The dynamic and bright effect was moving in a vertical direction when the substrate was tilted around a horizontal axis, while the shimmering spot dynamic effect was moving across the shell of said turtle when the substrate was tilted around the same horizontal axis.

[0189] The OELs of example E1-E3 were identical when observed from both the recto and the verso sides of the substrate although less reflective and bright when observed from the verso side.

[0190] The OELs of examples E4-E5, when observed from the side of the substrate carrying the first and second coating layers as well as from the side of the substrate carrying the third coating layer, provided a highly reflective image of a turtle with a dynamic effect in the form of a rolling bar, said dynamic effect being particularly visible within the head and legs areas of said turtle, and a particularly highly reflective shell of said turtle area with a shimmering spot dynamic effect. The dynamic and bright effect was moving in a vertical direction when the substrate was tilted around a horizontal axis, while the shimmering spot dynamic effect was moving across the shell of said turtle when the substrate was tilted around the same horizontal axis. The OELs of examples E4-E5 displayed a gold-to-green color travel effect when observed at face viewing angle and at side viewing angle from the recto side of the substrate; when observed from the verso side, the OELs of examples E4-E5 displayed a gold-to-green color travel effect within the head and legs areas of said turtle, and mainly a green-to-blue color travel effect within the shell areas of said turtle, when observed at face viewing angle and at side viewing angle.

Claims

1. A process for producing an optical effect layer (OEL) on a substrate (x10), said optical effect layer (OEL) comprising a first motif comprising magnetically oriented platelet-shaped magnetic or magnetizable pigment particles oriented according to a first magnetic pattern and a second motif comprising magnetically oriented platelet-shaped magnetic or magnetizable pigment particles oriented according to a second magnetic pattern, said process comprising:

a first set of steps consisting of

- a') applying onto the substrate (x10) a first radiation curable coating composition, preferably a first UV-Vis-curable curable coating composition, comprising the platelet-shaped magnetic or magnetizable pigment particles so as to form a first coating layer (x20') on said substrate (x10), said coating composition being in a first state,

b') exposing the first radiation curable coating composition of step a') to a magnetic field of a magnetic assembly (x30') so as to magnetically orient at least a part of the platelet-shaped magnetic or magnetizable pigment particles;

c') at least partially curing the first radiation curable coating composition of step b') to a second state so as to fix the platelet-shaped magnetic or magnetizable pigment particles in their adopted positions and orientations and so as to produce the first motif; and

a second set of steps consisting of

a") applying in register a second radiation curable coating composition, preferably a second UV-Vis-curable coating composition, comprising platelet-shaped magnetic or magnetizable pigment particles so as to form a second coating layer (x20"), said coating composition being in a first state, and at least a part of the second coating layer (x20") being adjacent to at least a part of the first coating layer (x20')

b") exposing the second radiation curable coating composition of step a") to a magnetic field of a magnetic assembly (x30") so as to bi-axially orient at least a part of the platelet-shaped magnetic or magnetizable pigment particles to i) have both their X-axis and Y-axis substantially parallel to the substrate (x10) surface, or ii) have their X-Y plane parallel to an imaginary spheroid surface;

c") at least partially curing the second radiation curable coating composition of step b") to a second state so as to fix the platelet-shaped magnetic or magnetizable pigment particles in their adopted positions and orientations and so as to produce the second motif.

2. The process according to claim 1, wherein step b') is a one-step orientation step or a two-step orientation step comprising a first orienting step to bi-axially orient the platelet-shaped magnetic or magnetizable pigment particles followed by a second orienting step to re-orient the platelet-shaped magnetic or magnetizable pigment particles.

3. The process according to claim 2, wherein step b') is a two-steps orientation step comprising the first orienting step to bi-axially orient the platelet-shaped magnetic or magnetizable pigment particles followed by the second orienting step to re-orient the platelet-shaped magnetic or magnetizable pigment particles.

4. The process according to any one of claims 1 to 3, wherein the first orienting step of the two-steps orientation step b') is carried out to bi-axially orient at least a part of the platelet-shaped magnetic or magnetizable pigment particles to i) have both their X-axis and Y-axis substantially parallel to the substrate (x10) surface, or ii) have a first axis within the X-Y plane substantially parallel to the substrate (x10) surface and a second axis being perpendicular to said first axis at a substantially non-zero elevation angle to the substrate (x10) surface, or iii) have their X-Y plane parallel to an imaginary spheroid surface.

5. The process according to any one of claims 1 to 4, wherein the first radiation curable coating composition and the second the first radiation curable coating composition exhibit a same color.

6. The process according to any one of claims 1 to 4, wherein the first radiation curable coating composition and the second the first radiation curable coating composition exhibit different colors.

7. The process according to any of claims 1 to 6, wherein the steps a') and a") are independently carried out by a printing process selected from the group consisting of screen printing, rotogravure, flexography printing and intaglio printing, preferably by screen printing.

8. The process according to any one of claims 1 to 7, wherein the step c') is carried out partially simultaneously with step b') and/or the step c") is carried out partially simultaneously with step b").

9. The process according to any of claims 1 to 8, wherein the step c') is carried out by exposure to UV-Vis light radiation with a LED curing unit (x50') and/or the step c") is carried out by exposure to UV-Vis light radiation with a LED curing unit (x50").

10. The process according to any one of claims 1 to 9, wherein at least a part of the platelet-shaped magnetic or magnetizable pigment particles is constituted by platelet-shaped optically variable magnetic or magnetizable pigment particles.

11. The process according to any one of claims 1 to 10, wherein the substrate (x10) is selected from the group consisting

of papers or other fibrous materials, paper-containing materials, glasses, metals, ceramics, polymers, metalized polymers, at least partially opacified polymers composite materials and mixtures or combinations thereof.

12. The process according to claim 11, wherein the substrate (x10) is a transparent substrate.

13. The process according to any of claims 1 to 12, wherein the optical effect layer (OEL) comprises the first motif comprising magnetically oriented platelet-shaped magnetic or magnetizable pigment particles oriented according to the first magnetic pattern, the second motif comprising magnetically oriented platelet-shaped magnetic or magnetizable pigment particles oriented according to the second magnetic pattern and a third motif comprising magnetically oriented platelet-shaped magnetic or magnetizable pigment particles oriented according to a third magnetic pattern, further comprising a third set of steps consisting of:

a''') applying onto a side of the substrate (x10) lacking the first coating layer (x20') and lacking the second coating layer (x20'') in register a third radiation curable coating composition, preferably a third UV-Vis-curable curable coating composition, comprising platelet-shaped magnetic or magnetizable pigment particles so as to form a third coating layer (x20'''), said coating composition being in a first state, and at least a part of the third coating layer (x20''') being adjacent to at least a part of the first coating layer (x20') and/or adjacent to at least a part of the second coating layer (x20''), or

a''') applying onto the side of the substrate (x10) comprising the first coating layer (x20') in a cured state and lacking the second coating layer (x20'') in register a third radiation curable coating composition, preferably a third UV-Vis-curable curable coating composition, comprising platelet-shaped magnetic or magnetizable pigment particles so as to form a third coating layer (x20'''), said coating composition being in a first state, and at least a part of the third coating layer (x20''') being adjacent to at least a part of the first coating layer (x20') and/or adjacent to at least a part of the second coating layer (x20''), or

a''') applying onto the side of the substrate (x10) comprising the second coating layer (x20'') in a cured state and lacking the first coating layer (x20') in register a third radiation curable coating composition, preferably a third UV-Vis-curable curable coating composition, comprising platelet-shaped magnetic or magnetizable pigment particles so as to form a third coating layer (x20'''), said coating composition being in a first state, and at least a part of the third coating layer (x20''') being adjacent to at least a part of the first coating layer (x20') and/or adjacent to at least a part of the second coating layer (x20''), or

a''') applying onto the side of the substrate (x10) comprising the first coating layer (x20') and the second coating layer (x20'') in a cured state in register a third radiation curable coating composition, preferably a third UV-Vis-curable curable coating composition, comprising platelet-shaped magnetic or magnetizable pigment particles so as to form a third coating layer (x20'''), said coating composition being in a first state, and at least a part of the third coating layer (x20''') being adjacent to at least a part of the first coating layer (x20') and/or adjacent to at least a part of the second coating layer (x20'');

b''') exposing the third radiation curable coating composition of step a''') to a magnetic field of a magnetic assembly (x30''') so as to bi-axially orient at least a part of the platelet-shaped magnetic or magnetizable pigment particles; and

c''') at least partially curing the second radiation curable coating composition of step b''') to a second state so as to fix the platelet-shaped magnetic or magnetizable pigment particles in their adopted positions and orientations and so as to produce the third motif.

14. The process according to any one of claim 1 to 15, wherein the substrate (x10) comprises a printed pattern, preferably an offset printed pattern, and wherein at least one of the radiation curable coating compositions of steps a') and a'') is applied at least partially on said printed pattern.

15. The process according to any one of claim 1 to 14, wherein the first coating layer (x20) and the second coating layer (x20') are within a register of ± 1 mm, preferably ± 0.5 mm and more preferably ± 0.2 mm.

Fig. 1

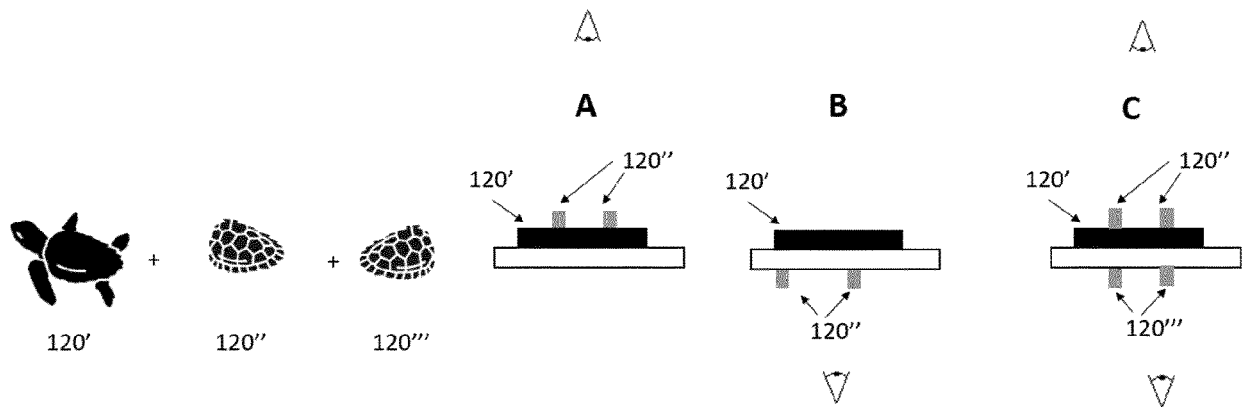


Fig. 2

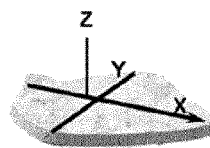


Fig. 3A

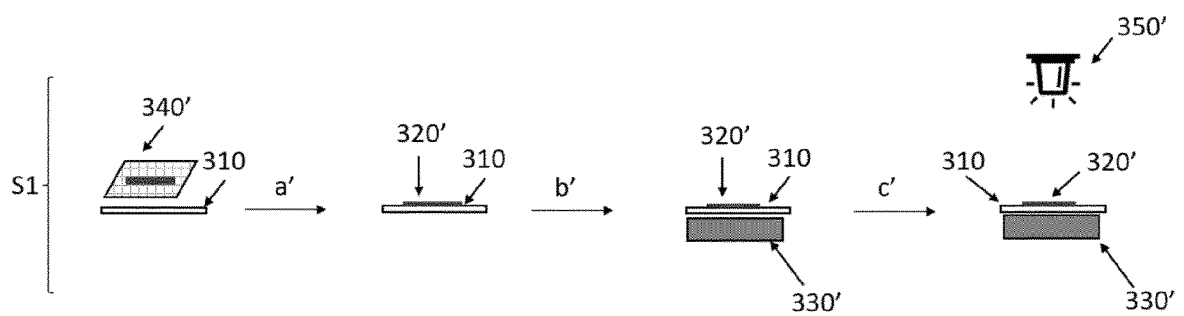


Fig. 3B

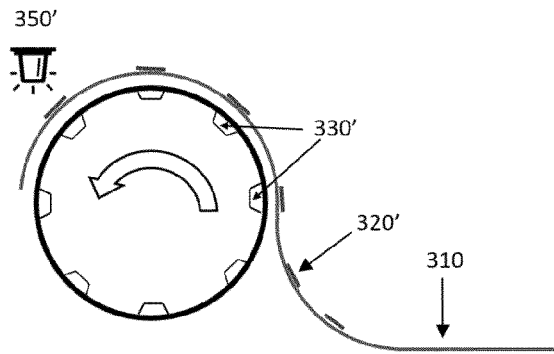


Fig. 3C

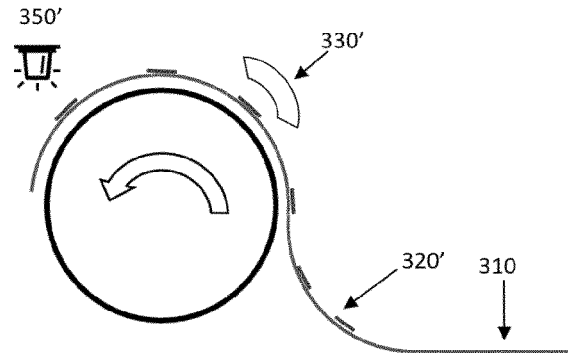


Fig. 4A

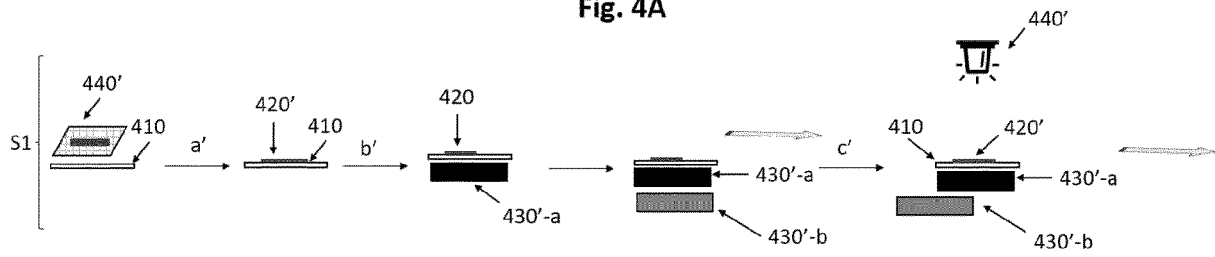


Fig. 4B

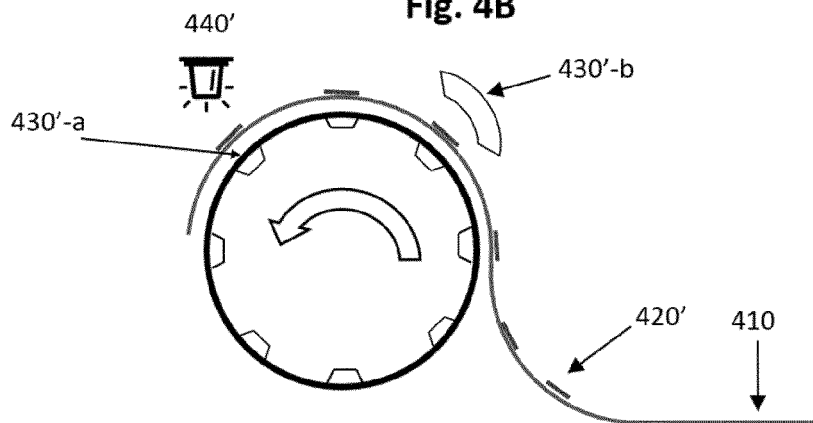


Fig. 5A

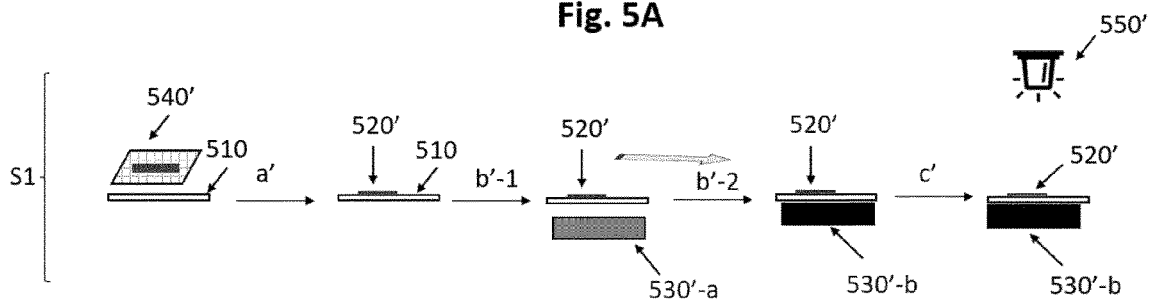


Fig. 5B

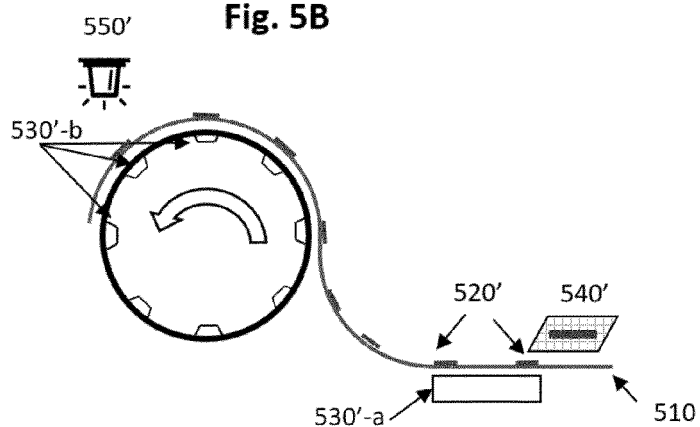


Fig. 6A

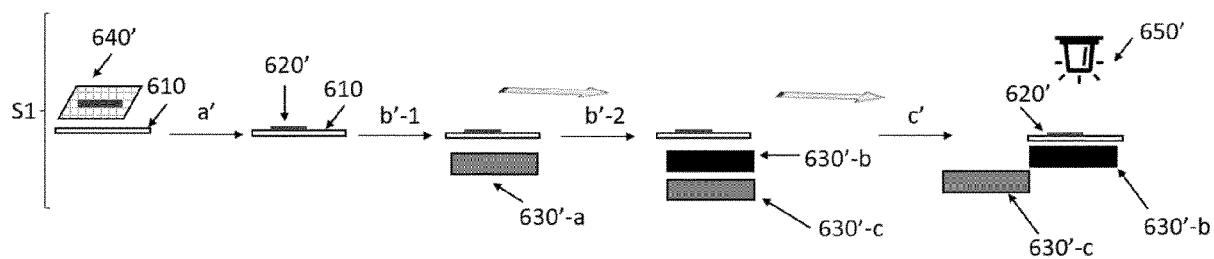


Fig. 6B

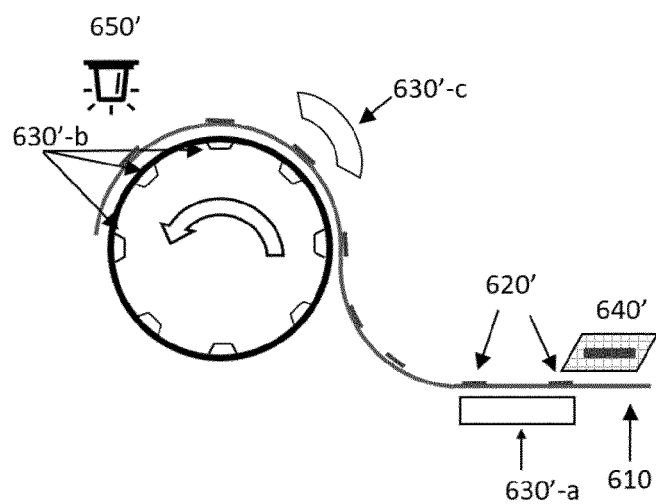


Fig. 7A

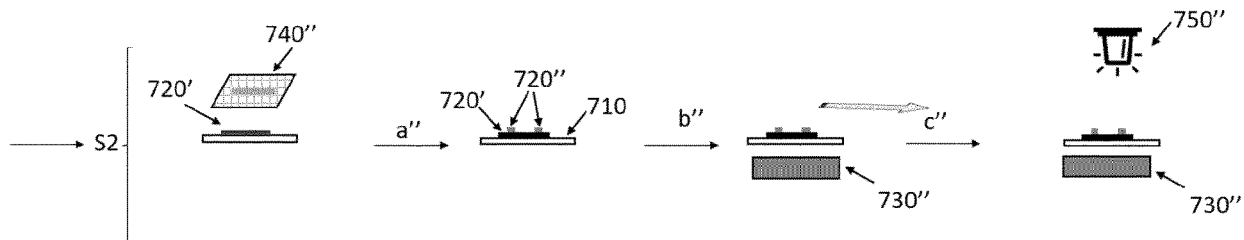


Fig. 7B

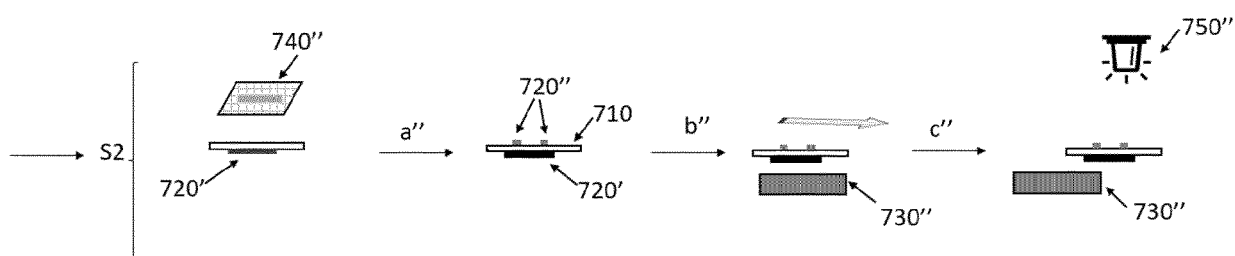


Fig. 7C

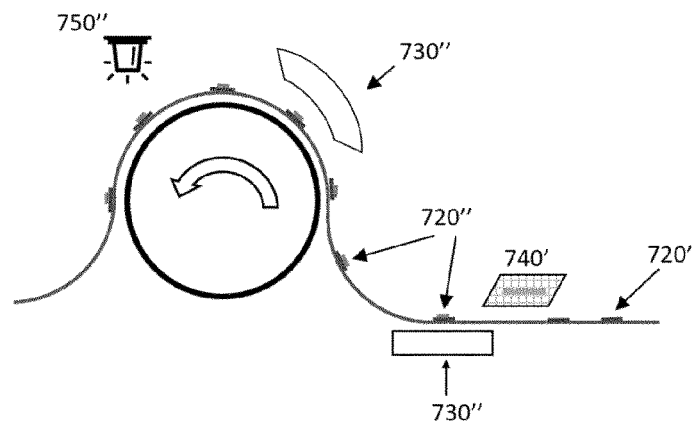


Fig. 8A

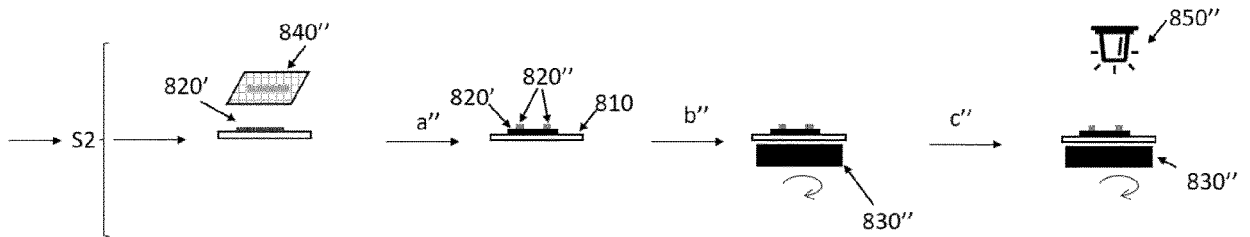


Fig. 8B

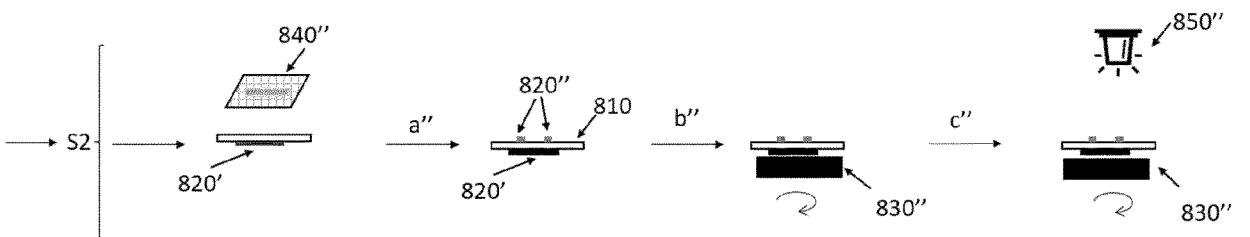


Fig. 8C

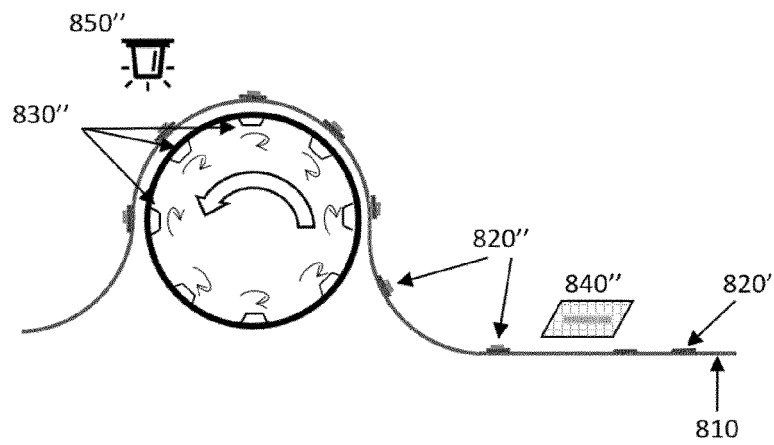


Fig. 9

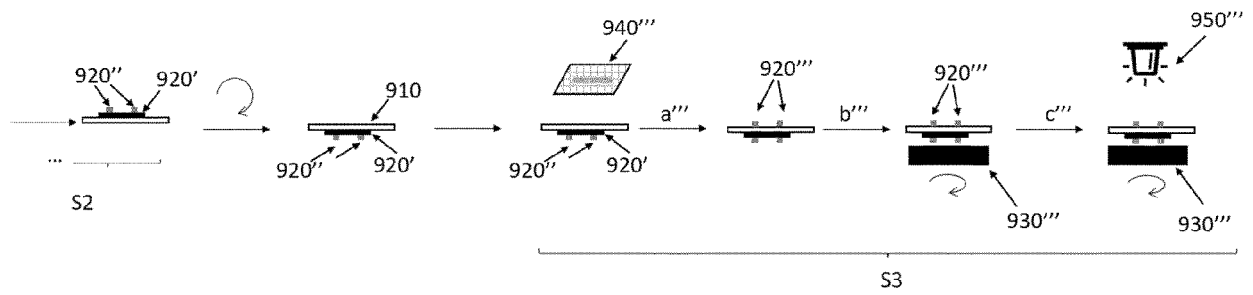


Fig. 10

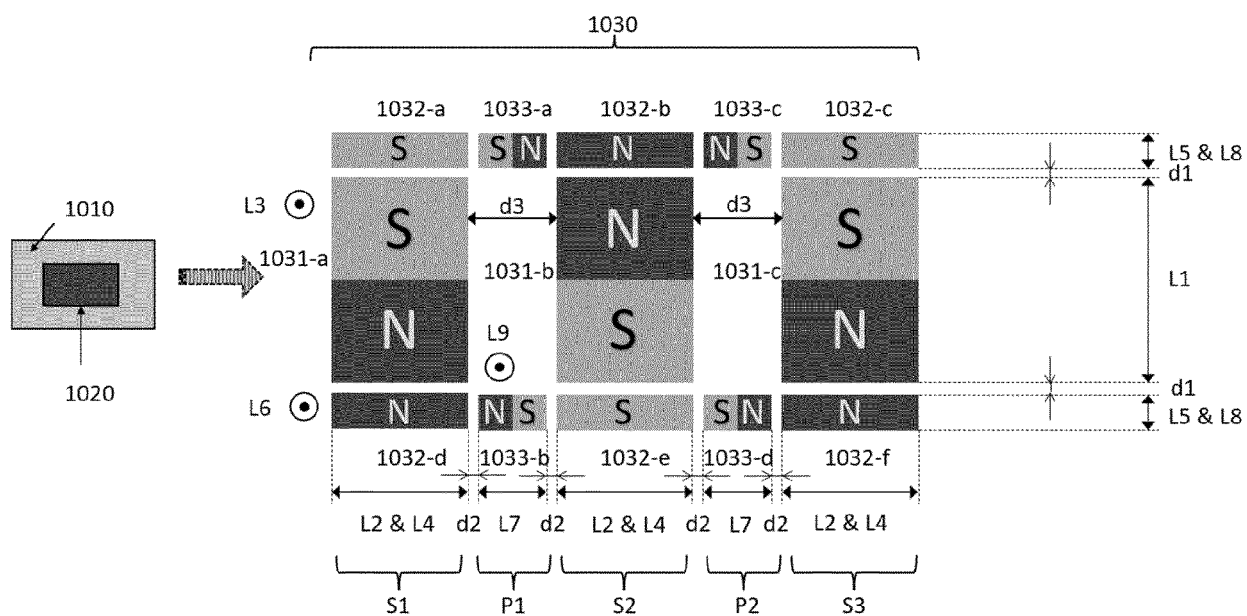


Fig. 11

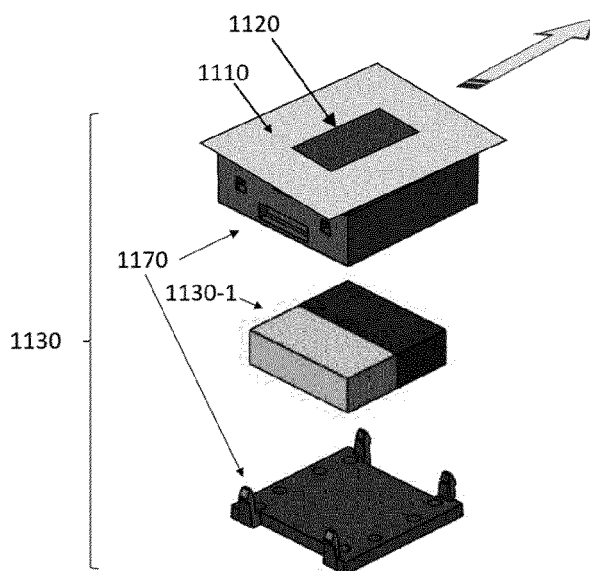


Fig. 12

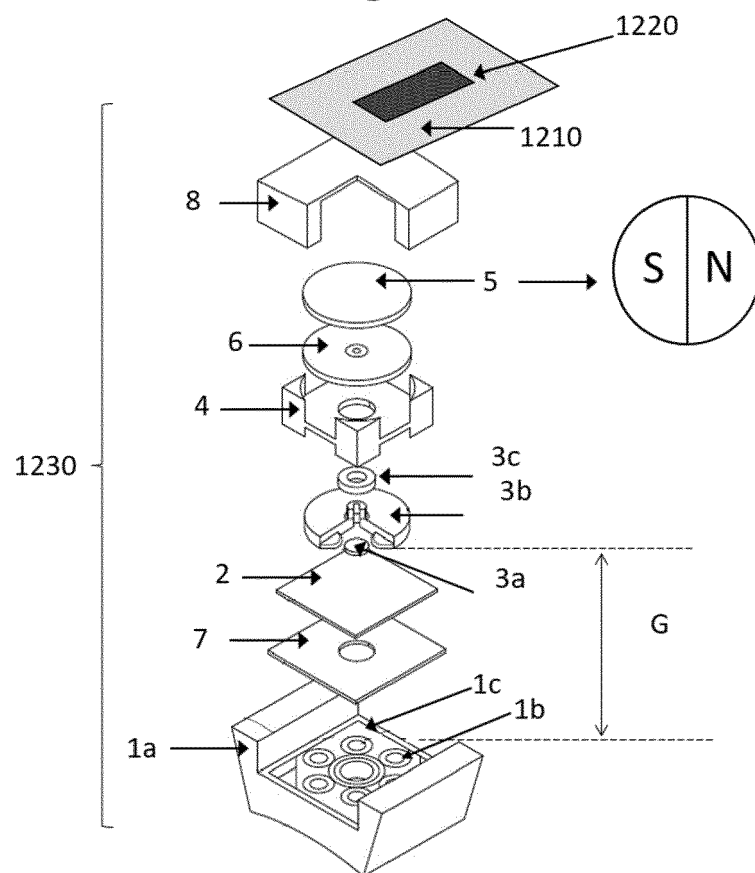
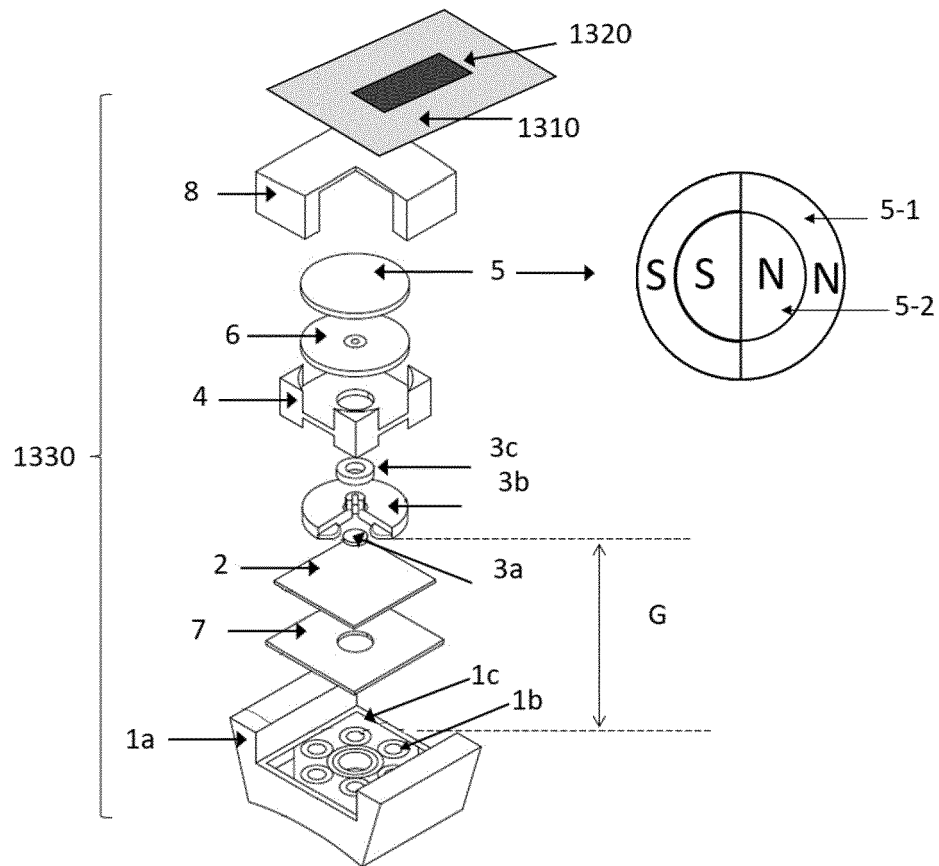


Fig. 13



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