

The invention relates to an optically variable surface pattern of the kind set forth in the classifying portion of claim 1.

5 Optically variable surface patterns of that kind, with a microscopic relief structure, are suitable for example for enhancing the level of safeguard against forgery and for enhancing the conspicuous identification of articles of all kinds and can be used in particular in relation to value-bearing papers, passes, means of payment and similar articles which need to be safeguarded.

10 The embossed relief structures with an optically effective coating cause diffraction of the light which falls onto the structure. The diffraction properties of those relief structures are determined inter alia by the spatial frequency, that is to say the number of lines
15 per mm, by the profile shape of the relief structure and by the amplitude or differences in height in the relief structure, as well as by the azimuthal orientation of the relief structure on the article to be safeguarded.

20 The relief structures have for example cross-sectional shapes of known periodic functions, with the spatial frequencies of more than 10 lines per mm, which are effective for the diffraction of visible light. Limits caused by the manner of manufacture restrict the range which can be used in a practical context to about 5,000 lines/mm. However, it is
25 also possible to use cross-sectional shapes with aperiodic functions which locally contain a spatial frequency mix out of that range, such as for example matt structures. The difference in height of those relief structures is typically selected to be between 50 nm and 10,000 nm.

30 The diffraction properties of the various relief structures are described for example in R. Petit, Electromagnetic Theory of Gratings, Springer Verlag, Berlin Heidelberg New York 1980.

35 Those structures can be inexpensively produced by deformation of a thermoplastic layer with a heatable embossing punch which in that respect carries the relief-like negative of the security element, which negative is galvanically cast from a master structure, as is known from Swiss patent specification No 594 936.

40 A surface pattern of the kind set forth in the classifying portion of claim 1 and another method of producing the master structure for the embossing punch of such surface patterns are described in Swiss application No 00805/88-4.

45 On the other hand holograms are known for the production of a three-dimensional image impression. The optical information concerning each point of a holographically registered, diffusely reflecting object is distributed over the entire active surface of the hologram so that a reduction in the hologram area causes an only immaterial decrease in the

size of the visible image portion but reduces the usable range in regard to the angle of view.

5 A method of producing a relief structure from a hologram is described in US patent specification No 4 094 575. That relief structure can be embossed into a plastics foil and can be reproduced. Such structures are visible only with difficulty when lit by means of surface lamps such as for example fluorescent lamps.

10 The invention is based on the problem of providing a light-modifying surface pattern which is difficult to copy and which changes in a predetermined manner, with at least two different representations of graphic configuration, which can be viewed at different angles of observation and whose authenticity can be optically perceived even by lay
15 persons, when lit normally by daylight or artificial light.

The invention is characterised in claim 1. Developments of the invention are set forth in the appendant claims.

20 Embodiments of the invention are described in greater detail hereinafter with reference to the drawing in which:

Figure 1 shows a surface pattern with a graphic representation which is divided into surface portions and grid areas, and,
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Figure 2 shows the structure of a grid area in detail and the diffraction of incident light at a diffraction element.

In Figure 1, reference numeral 1 identifies a boundary, of any
30 shape, of a surface pattern, reference numeral 2 identifies various surface portions of a representation of graphic configuration, reference numerals 3, 4 identify a carrier of the surface pattern, reference numeral 5 identifies an article which has a surface pattern as a security element, reference numeral 6 identifies a plurality of grid areas,
35 reference numeral 7 identifies various area portions of the grid area 6 and reference numeral 8 identifies a diffraction element.

In the embodiment illustrated by way of example, what is shown is a house comprising the three surface portions 2, the roof, the wall and
40 the door, and a background which is illustrated by means of a fourth surface portion 2. Each surface portion 2 is divided into grid areas 6, wherein limits between the surface portions 2 and the boundary 1 are composed bit by bit from the limits of the grid areas 6. Advantageously all surface portions 2 have grid areas 6 of the same size.

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The surface pattern may be for example only a part of a larger motif of graphic configuration, which is produced using another method of production. The boundary 1 is at least partially surrounded by that motif. The parts of the motif, which are not associated with the surface

pattern, are produced for example by means of the method known from Swiss application No 00 805/88-4 or are produced by means of a conventional printing process.

5 The entire surface pattern is composed of M grid areas 6, wherein M is at least of the value of two. For surface patterns which are graphically demanding, an area which is delimited by the boundary 1 is to be divided into a large number of grid areas 6 so that the grid areas 6 are no longer perceived as disturbing by the naked eye at the normal
10 viewing distance of about 30 cm.

In an example, all M grid areas 6 are of the same size. They cover the surface within the boundary 1 and are of a circular shape or are in the shape of a regular polygon, the diameter or a largest diagonal
15 line being less than 0.3 mm. A square drawing with a side length of 12 mm therefore has a value of M of more than 1600.

Each grid area 6 is divided into at least two area portions 7 which are identified by 7a to 7f in Figure 2. A regular polygon can
20 advantageously be used as the shape of the grid areas 6 as such polygons can be easily subdivided into regular other polygons of the grid portions 7, in such a way as to cover a surface. Triangles, quadrilaterals or hexagons are highly suitable.

25 Each grid portion 7 contains an optically active diffraction element 8 which has a microscopic relief structure 9 with a spatial frequency of more than 100 lines per mm. The diffraction element 8 diffracts incident light 10 in a manner which is predetermined by the relief structure 9.
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For reasons relating to the drawing, in Figure 2 one of the narrow sides of the central grid area 6 which is divided into six grid portions 7a to 7f is shown as a section surface in order to show the structure of the carrier 4. Likewise, for better understanding, the grid
35 areas 6 are indicated with a double separating line and division of the area portions 7a to 7f is indicated by a thick line. In actual fact the divisions are determined only by the various relief structures 9.

40 The relief structures 9 of the surface pattern are embossed into the carrier 4 by an embossing punch and then covered with a protective layer 11. An optically effective intermediate layer which is disposed between the protective layer 11 and the relief structure 9 which is embossed into the carrier 4 determines the mode of observation of the surface pattern:
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The surface pattern can be observed in a transmission mode if the protective layer 11 and the carrier 4 comprise optically transparent materials which have different refractive indices. The jump in refractive index which occurs at the transition from the protective layer

11 to the carrier 4 acts as an optically effective intermediate layer.

5 If the optically effective layer is a thin reflecting metal layer, for example of aluminium, gold, nickel, silver etc., which is applied to the carrier before or after the embossing operation, then the surface pattern can be observed in a reflection mode through the protective layer 11. The diffraction elements 8 reflect the incident light 10 which was modified by the diffraction effect, with a great degree of intensity.

10 The carrier 4 can also be fixed on non-transparent articles 5 and is therefore versatile in use. For example the carrier 4 can be provided with an adhesive layer 12 on the non-embossed side and can be stuck in the form of self-adhesive labels onto the article 5 to be safeguarded. 15 In the event of an attempt at separating the carrier 4 from the article 5, the adhesion forces of the adhesive layer 12 deform the carrier 4 with the relief structures 9 and thereby destroy the surface pattern.

20 The surface pattern has a reference direction 13 in the plane of the carrier 4. Relative to the reference direction 13, the direction of orientation 14 of each relief structure 9 can be determined by an azimuth angle ϕ between the two directions 13 and 14.

25 When designing the surface pattern, its overall surface is divided into M grid areas 6, each grid area 6 in turn having N area portions 7a to 7f. The two numbers M and N are whole and greater than 1.

30 The surface pattern includes N representations 3, one thereof being shown in Figure 1. Each of the N representations is divided into M grid areas or pixels corresponding to the division of the grid areas 6. Each of the N representations associates with one of the N area portions 7a to 7f the pixel corresponding to the grid area 6. Each pixel has as its parameters a colour value and a brightness value in respect of surface brightness.

35 The direction of the light 10 which is incident on the surface pattern (see Figure 2) and a direction of observation 15 which is intended for the representation 3 and which is related to the direction of orientation 14, and the colour value of the pixel, determine the 40 important parameters of the relief structure 9 of the diffraction element 8 associated with the respective pixel.

45 If the relief structures 9 are simple straight-line diffraction gratings, spatial frequency, azimuth angle ϕ and relief profile are sufficient as the parameters of the relief structures 9. The spatial frequency and the wavelength of the light 10 determine the diffraction angle θ .

50 Asymmetrical relief profiles are particularly advantageous as, with suitable dimensioning of the profile, the light 10 which is incident

from certain directions is almost entirely diffracted at those profiles into a predetermined spatial direction 17 or it is possible to achieve a given ratio which differs from 1:1 between the levels of intensity of the light which is diffracted into the plus first and the minus first
 5 diffraction order. That property of asymmetrical relief profiles is described for example in the above-mentioned publication by R. Petit, Electromagnetic Theory of Gratings, on pages 159 ff.

The spatial direction 17 of diffracted light 16 is determined by
 10 the azimuth angle ϕ and the diffraction angle θ , wherein the azimuth angle ϕ is of a predetermined value in the range of from 0° to 360° . In the case of symmetrical profiles, perpendicularly incident light is uniformly distributed to the two possible spatial directions 17 (θ, ϕ and $\theta, \phi+180^\circ$). Symmetrical relief profiles can be recognised from the fact
 15 that each representation 3 is visible in two different directions 15 of observation. On the other hand, in the case of suitably dimensioned asymmetrical profiles, each of the N representations 3 is visible only in a single direction 15 of observation. A surface pattern which has both symmetrical and asymmetrical kinds of profiles is admittedly more
 20 expensive to manufacture but gives particularly striking optical effects.

The spatial frequency can be modulated within a diffraction element 8 with a predetermined spatial frequency amplitude A so that the diffracted light 16 fans out into a region of the diffraction angle θ ,
 25 which is predetermined by the amplitude A. That is particularly advantageous if the carrier 4 is very thin and the article 5 is not entirely flat, such as for example the paper of a crumpled banknote. The surface pattern remains easily visible in spite of the unevenness, as a part of the diffracted light 16, in the range of the diffraction angle θ ,
 30 falls into the direction 15 of observation and thus compensates for the unevenness of the carrier 4.

The brightness values, which are to be represented with the predetermined direction of the incident light 10 and the direction 15 of
 35 observation, of the N pixels associated with a grid area 6 establish the relative size of the N area portions 7a to 7f or, if each of the grid areas 6 is fixedly divided into N area portions 7a to 7f, the size of a diffraction area 18 of the diffraction element 8 in each of the N area portions 7a to 7f. The light 16 which is diffracted at a predetermined
 40 angle θ is of an intensity which, irrespective of the conditions in regard to lighting and observation and the profile shape, depends on the effective diffraction surface 18 of the diffraction element 8 and the efficiency of diffraction of the relief structure 9.

45 If for example the proportion of the N diffraction areas 18 in the grid area 6 is determined by the brightness value of the pixel of each representation 3, the grid areas 8 which are observed in the predetermined direction 15 have differences in respect of their relative brightnesses.

In another embodiment the N area portions 7a to 7f are of equal size but the relief structures 9 are predetermined with a diffraction efficiency which is associated with the brightness value of the pixel.

5 Associated with each grid area 6 (Figure 1) is a predetermined pixel from each of the N various representations 3. Therefore in each of the N area portions 7 each grid area 6 has a diffraction element 8 which corresponds to the predetermined pixel of those N representations 3 and the relief structure 9 thereof and the size of the diffraction area 18 are predetermined by the parameters of the pixel. Therefore each grid
10 area 6 contains the entire information concerning the associated pixel of the N representations.

As each of the N different representations 3 has at least one
15 observation direction 15 associated therewith, an observer of the surface pattern, in non-diffuse lighting, sees only one of the N representations 3, from one of the N observation directions 15. All N representations 3 become successively visible to the observer by the carrier 4 being tilted or turned.

20 In Figure 2 for example N=6 because the surface pattern contains six representations 3. The diffraction element 8 which corresponds to the pixel of the first representation 3 is associated with the area portion 7a. The area portion 7b is intended for the pixel of the second
25 representation 3, and so forth. The N area portions 7a to 7f are of the same size. The diffraction area 18 which corresponds to the relative brightness is smaller or equal to the area of the area portions 7a to 7f. In Figure 2 the diffraction areas 18 are shown in hatching. A surface portion 19 of the area portions 7a, 7c and 7d, which is not occupied by
30 the diffraction element 8, is completely smooth and reflects the incident light 10. As the direction of the reflected light is determined by the law of reflection, its direction is also predetermined and may coincide with none of the observation directions 15 as reflection interferes with recognition of the representation 3.

35 It is possible to impress into the surface portion 19 a matt structure which uniformly scatters the incident light 10 in all directions and does not cause difficulties because of the low level of intensity when observing one of the N representations 3.

40 The N representations 3 may be different perspectives of one and the same object, in which case for example the directions of viewing of the corresponding views of the object may coincide with the N directions of observation 15. By changing the direction of observation 15, for
45 example by turning the surface pattern or by moving the head, in contrast to a hologram that gives an abruptly changing view of the object from the corresponding direction of observation 15. If for example the object is a human face, the changing object has a particularly striking effect on the viewer.

In another embodiment, among the N directions of observation 15, it is only the shading of an object that changes at a predetermined perspective, giving the impression of a varying direction of illumination of the object.

5 Particularly suitable for the N representations 3 which correspond to the N directions of observation 15 are also individual digits, letters, company logos, parts of texts etc. which become successively visible to the viewer in accordance with the direction of
10 observation 15 when the surface pattern is turned.

When the surface pattern is used on a banknote of a multilingual country, each of the N representations 3 may show for example the value
15 of the note in digits or in words in one of the languages of the country.

The directions of observation 15 may be arranged in pairs in such a way that, at the normal observation distance, the two directions of observation 15 of each pair just coincide with the extended axes of the two eyes of the observer, which are directed onto the surface pattern.
20 If the representations 3 which are visible at the two directions 15 form a stereoscopic pair of the same object, the person observing the surface pattern has a spatial impression of the object from a viewing direction which is predetermined for each of those pairs.

25 Finally the N representations 3 which correspond to the N directions of observation 15 may contain a time sequence of situations. When the surface pattern is turned, the viewer sees a temporal progression of actions, wherein the representation 3 corresponding to the direction of observation 15 is successively visible to the viewer.
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The graphic representation 3 is advantageously a black-and-white photograph of an object, which has been put into grid form, wherein the individual pixels have a brightness value of at least two stages.

35 The N representations 3 of the surface pattern may also be composed of the above-listed examples. In that respect it is also possible to blend image and text. The limits are set only by the technically possible resolution in M x N area portions 7 at a predetermined spatial frequency.
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The above-mentioned direction of the incident light 10 and the mentioned directions of observation 15 relate to a coordinate system which is defined by the surface pattern, wherein the parameters of the relief structures 9 of the corresponding pixels are each selected for a
45 respective fixed direction of the incident light 10 such that a viewer who moves his eyes around a spatially fixed surface pattern perceives the described changes.

In another embodiment the predetermined parameters of the relief

structures 9 provide that the N representations 3 become successively visible, even with a spatially fixed direction of the incident light 10 and an immobile viewer, if the plane of the surface pattern is moved about one of its axes by tilting. When that happens, the direction of the incident light 10 and the direction of observation 15 change at the same time in relation to the coordinate system which is fixed by the surface pattern.

Two particularly striking consequences of the successively visible N representations 3 upon tilting of the vertical axis of the plane of the surface pattern are mentioned by way of example:

- the perspective of the view of the object does not change in the tilting movement; and
- the perspective changes as if the object were also turned with the surface pattern.

The surface pattern is produced for example by the steps described hereinafter.

Firstly the N representations 3 are set to the predetermined dimensions for example by way of optical means and divided into equal-size pixels. The colour value and the stage of the brightness value are determined for each pixel. The intended direction of observation 15 is then established for each representation 3.

Those items of information determine the parameters of the relief structure 9, the relative size of the diffraction element 8 and therewith the size of the surface portion 19 for each area portion 7 in each grid area 6.

A master structure for the embossing punch for the surface pattern can be produced on the apparatus described in Swiss application No 00805/88-4. The two parameters of the relief structure 9, the spatial frequency and the profile shape determine a type of die for producing the image of the diffraction surface 18 on a surface element of a thermoplastic cover layer, by means of the apparatus. The third parameter establishes the orientation direction 14 or the azimuth angle ϕ through which the die must be turned prior to the image-forming operation. Steps which are to be performed by that apparatus, for production of the master structure of the surface pattern, can be controlled by a digital control system.

The matt structure of the surface portions 19 can be formed on the cover layer by a special die like one of the relief structures 9.

This work is advantageously performed by means of a computer program relating to the design configuration of the surface pattern.

It is also possible for the matt structure to be first formed on the surface of the cover layer, in which case that is effected in the apparatus in accordance with Swiss application No 00805/88-4 or in a preceding separate working operation by means of embossing rollers. The
5 surface of the cover layer is then further embossed with the corresponding die for each diffraction surface 18.

Galvanically produced negatives for the embossing punches are made in known manner (Swiss patent specification No 594 936) from the
10 master structure and the surface patterns are embossed and applied.

CLAIMS

1. An optically variable surface pattern with a representation of graphic configuration which is divided up into M grid areas which
5 contain optically active diffraction elements with a spatial frequency of more than 10 lines per mm, characterised in that each grid area (6) has a maximum dimension of less than 0.3 mm and a division into N area portions (7a to 7f) each having a diffraction element (8), wherein each
10 diffraction element (8) corresponds to a predetermined pixel of one of N representations (3), and that the parameters of a relief structure (9) in each of the N diffraction elements (8) are predetermined by belonging to a surface portion (2), so that each of the N
15 representations (3) is visible from a predetermined direction of observation (15) of the surface pattern, wherein both M and N are greater than 1.
2. A surface pattern according to Claim 1, characterised in that at least one relief profile of the diffraction elements (8) is asymmetrical, and that the azimuth angle (Φ) of each of the N
20 diffraction elements (8) has a predetermined value in the range 0° to 360° .
3. A surface pattern according to Claim 1 or 2, characterised in that the shape of the grid areas (6) is a regular polygon, and that the
25 largest diagonal line of the polygon is a maximum of 0.3 mm.
4. A surface pattern according to one of Claims 1 to 3, characterised in that the relative size of the diffraction surface area (18) of each of the N diffraction elements (8) in the grid area (6)
30 corresponds to the relative, predetermined brightness of the grid area (6) for each of the N representations (3).
5. A surface pattern according to one of Claims 1 to 3, characterised in that the relative diffraction efficiency of each of
35 the N diffraction elements (8) in the grid area (6) corresponds to the relative predetermined brightness of the grid area (6) for each of the N representations.



6. A surface pattern according to Claim 4 or Claim 5, characterised in that each grid area (6) has N area portions (7a to 7f) of equal size.
- 5 7. A surface pattern according to Claim 6, characterised in that in each area portion (7a to 7f) a surface portion (19) not occupied by the diffraction element (8) has a matt structure.
- 10 8. A surface pattern according to one of Claims 4 to 7, characterised in that the N representations (3) of graphic configuration are views of one and the same object from various predetermined perspectives of the object.
- 15 9. A surface pattern according to one of Claims 4 to 7, characterised in that the N representations (3) of graphic configuration are views of one and the same object from a predetermined perspective of the object with different predetermined directions of illumination of the object.
- 20 10. A surface pattern according to one of Claims 4 to 7, characterised in that the N representations (3) are photographs put into grid form, and that the pixels of the surface portions (2) have at least two stages of brightness value.
- 25 11. A surface pattern according to one of Claims 4 to 8, characterised in that N is an even number and that the representations (3) are at least one stereoscopic pair of the same object, so that at least one three-dimensional view of the object is visible to the naked eye.
- 30 12. A surface pattern according to one of the preceding claims, characterised in that the surface pattern is only a part of a larger motif of graphic configuration, and that a boundary (1) of the surface pattern is at least partially surrounded by a motif which is produced
- 35 using a different technique.



13. A surface pattern according to one of the preceding claims, characterised in that a carrier (4), into which the surface pattern is embossed, has an adhesive layer (11) on the non-embossed side.