

The invention relates to a document having a security element with a diffraction-optical effect, of the kind set forth in the classifying portion of claim 1, as can be used as authenticity information which is difficult to falsify, in particular in relation to securities or stocks and shares, passes, means of payment and similar articles to be safeguarded, and a process for the production thereof.

Documents are not to be duplicatable. Modern documents therefore have security elements which for example by means of diffraction of ambient light make items of authenticity information on the safeguarded article visible even to the untrained lay person. A document of that kind and a process for the production thereof are described for example in Swiss patent specification No 529 936.

- Diffraction is caused by impressed grating structures with an optically active coating which in the simplest case are wave-like straight-line relief structures. The diffraction properties of those relief structures are determined inter alia by the spatial frequency, that is to say the number of lines per millimetre, the cross-sectional shape of the relief structure, the differences in height in the relief structure, and the orientation of the relief structure on the document.

German laid-open application (DE-OS) No 32 06 062 describes an accreditation arrangement, the diffracting structure of which is composed of surface portions with different structure parameters. Each individual surface portion is at least so large that the light which falls on the accreditation arrangement and which is broken up into its colour components in a characteristic manner occurs at a spacing of 25 cm as separate bundles of characteristic colours with a solid angle of at least 2 milliradians or about 7 minutes of arc. Those surface portions are therefore easily recognisable by the naked eye and stand out from the adjacent surfaces by for example contrasting colours.

If the grating parameters change continuously or from surface portion to surface portion in small steps within the diffractive structure, then colour impressions which move on a predetermined path occur on the document, from the point of view of the eye of the viewer, if the position of the document is changed in relation to the light source and the naked eye. Documents of that kind are described in EP No 105 099.

Those documents can be inexpensive produced by deforming a plastics layer with a heatable pressing punch which in that situation

bears a relief-like negative of the security element, which negative is to be galvanically shaped by a master structure.

5 A manner of manufacture of that master structure is known from EP No 169 326. A layer of plastics material is elastically deformed at the surface in a small circular zone by a die which carries a predetermined relief structure. By means of a beam of light, the surface which is towards the die is locally heated until the plastics material softens in a surface element delimited by the light beam and the relief structure is transferred on to the surface by plastic deformation. A master 10 structure produced in that way may comprise a large number of surface portions which differ from the adjacent ones in regard to their diffraction characteristics. Forgeability is made substantially more difficult by virtue of the large number of surface portions with different diffraction effects.

15 The invention is based on the problem of providing a document of the kind set forth in the opening part of this specification, and an apparatus for the production thereof, which document is distinguished by a structure which can be copied or forged only at a high level of 20 expenditure and which when considered visually has lines and surface elements which are visible without auxiliary means and which include additional graphic features which are not visible without auxiliary means.

25 The problem is solved by the characterising features of claims 1 and 7.

Embodiments of the invention are described hereinafter with reference to the drawings in which:

30 Figure 1 is a diagrammatic view of a document applied to an article to be safeguarded,

35 Figure 2 shows examples of surface portions of a diffractive structure,

Figure 3 shows a visual aspect of the document,

40 and Figure 4 shows an enlarged part of a surface portion of Figure 2,

Figure 5 shows apparatus for the production of a master structure for those documents.

45 A document 1 is shown in Figure 1, a part of the document 1 having been cut away to enhance comprehension. The surface 2 therefore shows the document 1 in cross-section. The document 1 comprises a substrate 3

with an optically effective coating 4 and a transparent protective layer 5.

5 The optically effective coating 4 is typically a thin metal or dielectric layer of a thickness of the order of magnitude of 100 nm, but the optical effect can also be produced solely by a difference between the refractive indices of the protective layer 5 and the substrate 3.

10 The substrate 3 may be for example a plastics foil for sticking on to an article 6 to be safeguarded. If the article 6 to be safeguarded is a paper, foil or fleece, the substrate 3 may also be a plastics layer which is applied directly to that substrate, by a printing procedure. If the article 6 to be safeguarded comprises plastics material, it may serve directly as a substrate, in other words the document 1 and the article 6 to be safeguarded form an inseparable unit. The document 1 is 15 difficult to forge or counterfeit and serves as an authenticity feature for passes, means of payment, securities or stocks and shares, certificates and the like. For example, a macroscopic structure 7 with a diffraction-optical effect is impressed into the substrate 3 by means of a heated punch prior to or after application of the optically effective coating 4. The wavelength of the light used for viewing the diffraction 20 effects and the choice of materials for the substrate 3, for the optically effective coating 4 and for the protective layer 5 determine whether the structure 7 with the diffraction-optical effect represents a phase or an amplitude grating and whether the structure 7 must be viewed in a transmission or a reflection mode. It is also possible to envisage 25 a combination of the two kinds of grating and/or the two viewing modes.

30 The structure 7 comprises a plurality of surface portions 8, 9, 10 with microscopic relief structures 12. A boundary 11 separates each surface portion 8, 9, 10 from the other, wherein the boundary 11 is only an aid for describing the shapes of the individual surface portions 8, 9, 10 and making them visible in the drawings. In actual fact the nature and orientation of the relief structure 12 define each of the surface portions 8, 9, 10. When the document 1 is viewed, the surface portions 35 8, 9, 10 differ from each other by virtue of the shapes of their boundary 11, and by their diffraction effects which are determined by the choice of the parameters involved and the orientation of the impressed relief structure 12.

40 The relief structures 12 are for example of cross-sectional shapes of known periodic functions with the spatial frequencies of more than 10 lines/mm, which are effective for the diffraction of visible light. Limits governed by manufacturing considerations restrict the range which can be used in practice to about 2500 lines/mm. However it is also 45 possible to use cross-sectional shapes with aperiodic functions which locally contain spatial frequencies from that range, for example matt structures. The difference in height of such relief structures 12 is

typically selected at between 50 nm and 10,000 nm.

In an embodiment of the document as shown in Figure 2, the surface portions 8 and 9 are surrounded by a surface portion 10 of the structure 7. For example the surface portion 8 differs from the adjacent surface portion 9 only in regard to its shape which is defined by the edge 11, while the surface portion 10 differs from the two immediately adjoining surface portions 8 and 9 by a relief structure 12' with different diffraction effects. Thus the surface portion 8 or 9 may represent a character, a digit or another feature which stands out from the surface portion 10 when the document 1 is viewed, by virtue of intensity and colour.

The normal-sighted human eye recognises the features of the surface portions 8 and 9 without auxiliary means as long as they appear at a viewing angle of somewhat more than 1 minute of arc. At the usual eye spacing of about 25 cm therefore the naked normal-sighted human eye recognises features without difficulties if the surface-defining details are at spacings of more than 0.1 mm. Therefore the dimensions of the surface portions 8 and 9 themselves must be a multiple of 0.1 mm in order to be able to distinguish their shapes, for example those of a character.

If the surface portion 8, 9 is of a largest dimension of 0.3 mm or less, then, depending on the level of contrast, at the usual eye spacing of the naked human eye, it is only perceived on the document 1 as a structure-less point 13 (see Figure 3).

In Figure 2 a plurality of surface portions 8, 9 with a maximum height h are disposed in a row, wherein the spacing of the surface portions is less than 0.3 mm and thus at the normal eye spacing is less than the spacing required for the minimum angle of view. From the point of view of the naked eye, they form on the document 1 a line 14 of a width b which is equal to the height h . If the width b is less than 0.3 mm, the line 14 has an unnoticeable, structure-less boundary.

The surface portions 8, 9 can be so fine that their surfaces which are defined by the edge 11 may represent for example a character, a digit or another feature of graphic configuration, without the largest dimension which is referred to as the width b or the height h exceeding about 0.3 mm. From the point of view of the naked eye, if the surface portions 8, 9 on the document 1 are perceived at all, they therefore appear as points 13 (see Figure 3) or lines 14.

Using those points 13 and lines 14 as raster elements, it is possible to form macroscopic patterns 15 which can be easily recognised by the naked eye on the document 1, without the artistic configuration of the patterns 15 being subject to any limits.

The naked eye only recognises the pattern 15 in the interplay of colours and luminosity, which is dependent on the viewing and illumination conditions and which is determined by the diffraction effect at the relief structures 12, 12', in front of the background of the diffraction effects of the structure 7, which are produced by the other surface portions 10.

For example, on the document 1 in a design intended for a banknote, a national emblem is contained in each point 13 and texts are contained in each line 14, the texts giving a reference to the issuer or the nominal value. Those additional items of information can only be detected when the diffractive structure 7 is viewed by means of a simple magnifying glass. An inspector can use that auxiliary means to detect characters, digits or other features which are concealed in the points 13 or lines 14 and in that way assure himself of the authenticity of the document 1.

In the case of characters, digits or features with a maximum dimension of less than 0.3 mm, line widths s (see Figure 4) of less than 60 μm are necessary for them to be of a good configuration. The surface portions 8, 9 are composed of circular surface elements 16 of a diameter s which corresponds to the finest line width s' . As shown in Figure 4 by means of the example of the character 'i', larger line widths s' may be composed of the mutually overlapping surface elements 16 which are used for the finest line widths.

Identical orientation and identical parameters in respect of the relief structure 12 in all surface portions 8, 9 which differ from those of the relief structure 12' of the surface portion 10 advantageously assists with recognisability. The inspector equipped with a magnifying glass can recognise those surface portions 8 and 9 of the same colour and the same luminosity, which stand out from the surrounding surface 10 in terms of colour and luminosity.

A group of characters (see Figure 2) can be repeated a number of times on a line 14. For example a group represents a sentence, wherein the surface portions 8, 9 for each word of the sentence are distinguished by a different relief structure 12 so that each word appears in a different colour and with different luminosity.

Impressing processes are to be preferred for rational mass production of documents 1 of that kind (see Figure 1), wherein a heated impressing die plastically deforms the surface of the substrate 3.

For the purposes of producing the impressing die, a master structure is advantageously produced on a carrier 17 by means of an apparatus as shown in Figure 15, and thereafter a negative is

galvanically shaped from that master structure, the negative then serving as an impressing die. The apparatus transfers one surface element 16 (see Figure 4) after the other from an unheatable die 18 on to a thermoplastic cover layer 19 of the carrier 17.

5 The apparatus comprises for example a radiation source 20 for electromagnetic radiation 21, a modulator 22 for modulating the intensity of the radiation 21, a focussing means 23, a beam deflection device 24, a rigid flat support 25 for the carrier 17 of the thermoplastic cover layer 19 and a means 26 for pressing the die 18 on
10 to the cover layer 19 which is enclosed between it and the carrier 17.

 It is also possible to envisage using the support 25 directly as the carrier 17 for the cover layer 19 in order to avoid reflection losses at the common interface 27 thereof. The support 25 only has to be
15 easily interchangeable for that purpose.

 The die 18 may be of a rigid or flexible nature and in the surface which is towards the cover layer 19 has a microstructure 28 of some square centimetres in area. In order to compensate for unevenness of the
20 cover layer 19 and in order to provide for uniform pressure distribution in respect of the cover layer 19, a flexible die 18 comprising a thin metal foil is advantageously used. A flexible intermediate layer 29 supports the rear side of the die 18 against the pressure-producing means 26.
25

 The means 26 presses the unheated die 18 with the surface bearing the microstructure 28 against the thermoplastic cover layer 19 in such a way that the microstructure 28 elastically deforms the cover layer 19 over the entire contact surface.
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 The electromagnetic radiation 21 passes through the transparent support 25 and the transparent carrier 17. The focussing means 23 concentrates the electromagnetic radiation 21 at a focal spot in the plane of the thermoplastic cover layer 19. The irradiated location is
35 displaceable by means of the beam deflection device 24, in the plane of the cover layer 19.

 Suitable agents such as dyestuffs or soot absorb in the cover layer 19 the radiation 21 which is controlled in respect of intensity by
40 means of the modulator 22, and locally heat the thermoplastic cover layer 19 at the irradiated location. The cover layer 19 softens in the surface element 16 (see Figure 4), in which respect dissipation of heat through the carrier 17 (Figure 5) and the die 18, radiant energy and the period for which the radiation 21 acts determine the diameter s (Figure
45 4) of the surface element 16. The local pressure of the die 18 (Figure 5) is sufficient to cause local plastic deformation of the hot cover layer 19. Controlled for example by the beam deflection device 22, the

irradiated location moves along in the cover layer 19, or the radiation 21 is cut out by the modulator 22. As soon as the radiation 21 no longer acts on the surface element 16 (Figure 4), the cover layer 19 (see Figure 5) hardens again and now has a permanent image of the microstructure 28 at that location.

A laser is advantageously used as the radiation source 20. For the purposes of shaping the microstructure 28, the radiation 21 can be so accurately focussed in the entire plane of the cover layer 19 that the irradiated location heats the cover layer 19 in surface elements 16 (Figure 4) whose diameters s are less than $60\text{ }\mu\text{m}$.

With the described apparatus it is possible to produce line widths s' of less than $60\text{ }\mu\text{m}$ in the master structure as the die 18 (see Figure 5) is not subjected to the action of any lateral mechanical forces which in the operation of shaping the microstructure 28 can uncontrollably displace the die 18 and thus restrict the line width s' (Figure 4) downwardly, in spite of good focussing of the radiation 21 (Figure 5). Line widths s' (Figure 4) of less than $60\text{ }\mu\text{m}$ are necessary for producing characters, digits and other features of graphic configuration if they are no longer to be recognised by the naked human eye. The writing speed is determined by the power of the radiation 21 (Figure 5) at the focal point.

In a first step the apparatus successively produces a group of surface portions 8, 9, 10 (Figure 2) of the structure 7 in the master structure, which enjoy the same orientation and the same parameters for the relief structure 12, 12'.

In a second embodiment of the apparatus, the image of an aperture plate (not shown here) in the modulator 22 is optically formed on the cover layer 19 by the focussing means 23 and heats the cover layer 19 in an aperture image to shape the microstructure 28. That apparatus also produces surface elements 16 (Figure 4) of a diameter s and line widths s' of more than $60\text{ }\mu\text{m}$ and accelerates the production of the master structure.

In a third embodiment of the apparatus the group of all surface portions 8, 9, 10 of the structure 7, which have the same orientation and the same parameters for the relief structure 12, 12', are produced simultaneously in the master structure. Instead of the aperture plate, use is made of an aperture with cut-out shapes of that group, for which purpose the image thereof is optically formed on the cover layer 19 by the focussing means 23 (Figure 5), in which case radiation which is advantageously of a pulse nature simultaneously heats the cover layer 19 at all irradiated locations of the aperture image so that images of the microstructure 28 which remain there are produced in the master structure.

The aperture members are mounted in the modulator 22 interchangeably and rotatably in order to afford the maximum degree of flexibility for the apparatus.

5 The die 18 is then lifted off the cover layer 19, rotated about an axis 30 which is normal to the plane of the die 18, laterally displaced or replaced by a die 18 with another microstructure 28.

10 In the following steps, further groups of surface portions 8, 9, 10 (Figure 4) are transferred with one of the above-described processes, in which case surface elements 16 of the cover layer 19 (Figure 5) can again be changed in shape. That shaping operation is repeated until all surface portions 8, 9, 10 (Figure 1) of the structure 7 have been produced.

15 In a fourth embodiment of the apparatus, instead of the beam deflection device 24 (see Figure 5), a controllable drive produces a mechanical relative movement between an irradiation source 31 which comprises the components 20; 22 and 23, and an assembly 32 comprising the components 17; 18; 19; 25; 26 and 29, the irradiated location, that is to say the focal spot or the aperture image, being displaced in the plane of the cover layer 19.

20 By using that apparatus, a small number of the expensive dies 18 are sufficient to produce an unlimited number of different master structures.

25 The entire radiation control operation, rotation and replacement of the dies 18 and the aperture members is advantageously allocated to a digital control system (not shown herein). That makes it possible not only to provide for optimum preparation of the control data but also to reproduce the master structure as frequently as may be desired, by means of the stored controlled data.

30 The microstructures 28 determine the nature of the relief structures 12, 12' (Figure 2) formed and are for example in the plane of the die 18 (Figure 5) periodic two-dimensional functions whose spatial frequencies are the same or different in the two dimensions, which frequencies extend from about 10 lines/mm to a limit value which is limited only by the shaping technique employed. Examples in that respect are simple linear gratings, cross gratings, point gratings etc.

35 Besides aperiodic or combinations of functions referred to above, more general profile structures which can only be produced with holographic means are also suitable as microstructures 28 in the dies 18.

40 Other dies 18 contain microstructures 28 with structures which have an anisotropically or isotropically light-diffusion effect. They

serve for producing matt and shiny locations as an additional configurational element in the pattern 15 (see Figure 3).

5 The microstructures 28 (Figure 5) are produced by means of mechanical processing methods such as scoring and the like, by means of microlithographic methods, for example by means of electron or X-ray lithography, or by means of chemical or physical etching methods.

CLAIMS

1. A document having a macroscopic structure (7) which is impressed over a large area and which has a diffraction-optical effect and which is composed of numerous surface portions (8, 9, 10) with predetermined relief structures (12, 12') having a diffraction-optical effect, with spatial frequencies of more than 10 lines/mm, wherein each surface portion (8, 9, 10) differs in its relief structure (12, 12') from those of the directly adjoining surface portion (8, 9, 10), characterised in that at least one group (8, 9) of the surface portions (8, 9, 10) is of a largest dimension of less than 0.3 mm.

2. A document according to claim 1 characterised in that those surface portions (8, 9) whose largest dimension is less than 0.3 mm are in the shape of a geometrical figure, a character, a digit or the like.

3. A document according to claim 1 or claim 2 characterised in that when viewed with the naked human eye it has at least one visually perceptible, straight or curved line (14) which is composed of those surface portions (8, 9) whose largest dimension is less than 0.3 mm and that said surface portions (8, 9) are disposed in a row, wherein the spacing thereof is less than 0.3 mm.

4. A document according to claim 3 characterised in that visually perceptible lines (14) and/or points (13), when viewed with the naked human eye, form a predetermined pattern (15).

5. A document according to one of the preceding claims characterised in that the optically effective structure (7) is impressed into an adhesive foil which is stuck on to an item (6) to be safeguarded.



6. A document according to one of claims 1 to 4 characterised in that the optically effective structure (7) is impressed into a layer which is applied by a printing process.

7. A process for the production of a master structure which serves for the galvanic shaping of pressing punches for impressing documents according to one of claims 1 to 6 and which is produced in a thermoplastic cover layer (19) which absorbs electromagnetic radiation (21), on a carrier (17) which is transparent to the electromagnetic radiation (21), wherein the cover layer (19) is elastically deformed by means of an unheated die (18) pressed thereagainst, with a predetermined microscopic microstructure (28), and wherein the radiation (21) which is controlled in its intensity and which is focussed on to the cover layer (19) through a support (25) and the carrier (17) provides that the cover layer (19) is locally temporarily melted, local plastic deformation occurs and the microstructure (28) with a diffraction-optical effect is transferred as a permanent image on to the cover layer (19) in a surface element (16), characterised in that the surface of the die with the microstructure (28) is uniformly pressed on to the entire cover layer (19), that the rear side of the die (18) is supported by means of a flexible intermediate layer (29) against a pressure-producing means (26), that substantially the entire surface of the cover layer (19) is elastically deformed and that it is only after the transfer of a predetermined number of surface portions (8, 9, 10) that the die (18) is turned about its axis (30), laterally displaced or replaced by a die (18) with another microstructure (28).

8. A process according to claim 7 characterised in that the image of an aperture disposed in the modulator (22) is formed on the cover layer (19) by means of the radiation (21) and the focussing means (23) and thereby the cover layer (19) is heated at an irradiated location of the image of the aperture.



9. A process according to claim 7 characterised in that the radiation (21) is projected by means of the focussing means (23) on to the cover layer (19) at a focal point and thereby the cover layer (19) is heated at the irradiated location.

10. A process according to one of claims 8 and 9 characterised in that the irradiated location is displaced in the plane of the cover layer (19) by means of a beam deflection device (24) and that the microstructure (28) is successively transferred in surface elements (16) on to the cover layer (19) at predetermined locations.

11. A process according to one of claims 8 and 9 characterised in that a relative movement is produced between an irradiation source (31) and an assembly (32) by means of a controllable drive, that the irradiated location is displaced in the plane of the cover layer (19) and that the microstructure (28) is successively transferred in surface elements (16) on to the cover layer (19) at predetermined locations.

12. A process according to one of claims 8 to 11 characterised in that the radiation (21) is simultaneously absorbed in a predetermined number of surface portions (8, 9, 10) in the cover layer (19) and that the same microstructure (28) is simultaneously transferred in the surface portions (8, 9, 10) on to the cover layer (19) at predetermined locations.