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(71) Applicant: Giesecke & Devrient GmbH, 81677 Munich, DE	(72) Inventor: Fuhse, Christian, Dr., 83624 Otterfing, DE

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(54) Title: **Security element with optically variable surface pattern**

(57) Abstract: The invention relates to security element (20) for security papers, value documents and other data carriers, with a substrate (22) which contains an optically variable surface pattern (26) in a surface region (24), which shows different representations with different lighting and/or viewing directions, the optically variable surface pattern (26) being formed of a plurality of facets (28) that substantially have a ray-optical effect, the dimensions of which are smaller than 30 μm in at least one direction of the plane of the surface region (24), and which are arranged aperiodically in the plane of the surface region (24).	
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Description

[0001] The invention relates to a security element for security papers, a value documents and other data carriers, the security element comprising an optically variable surface pattern in a surface region. The invention also relates to a method for manufacturing such a security element and a data carrier with such a security element.

[0002] Data carriers such as value documents or identification documents and also other valuable articles such as branded articles are often provided with security elements for safeguarding, which allow verification of the authenticity of the data carrier and at the same time serve to protect against impermissible reproduction. It is known here to protect holograms, holographic grating formers and other hologram-like diffraction patterns themselves against counterfeiting, which is achieved by introducing hidden image information into the diffraction patterns. Here, in addition to an original, openly visible image information, hidden piece of image information is embedded in the diffraction pattern which cannot be identified without special measures. An example of a diffraction pattern with such a hidden piece of information is described in publication WO 2005/038499 A2.

[0003] Such security elements are based on holograms generated by direct exposure or by computer-calculated diffraction grating arrangements. If such holograms are exposed to a laser beam, the light diffracted on the security element projects an illustration onto a screen. However, in addition to this desired direct representation a second so-called conjugate imaging occurs due to the symmetry of the diffraction grating.

[0004] In the case of directly exposed security elements and/or security elements consisting of symmetrical diffraction gratings, in particular the typical sinusoidal gratings, the direct image is as bright as the conjugate image. Since the conjugate image is generally reversed left to right, for aesthetic reasons and also to increase security against counterfeiting, attempts have already been made to create security features in which no or only a weak conjugate image occurs.

[0005] A possible method for generating such asymmetrical projections is described in publication EP 0 762 238 A1. Asymmetric diffraction patterns, in particular diffractive sawtooth gratings, are utilized, in which the first or minus first order of diffraction corresponding to the direct or conjugate image can have very different brightness.

[0006] Based thereon, the invention is based on the object of further improving a security element of the type mentioned at the outset and, in particular, of creating a security element that can be produced easily and inexpensively and has a high level of security against counterfeiting.

[0007] This object is achieved by the features of the independent claims. Refinements of the invention are the subject of the dependent claims.

[0008] According to the invention, a security element of the type mentioned at the outset contains an optically variable surface pattern, which is formed from a plurality of facets that substantially have a ray-optical effect, the dimensions of which are smaller than 30 μm in at least one direction of the plane of the surface region, and which are arranged aperiodically in the plane of the surface region. The facets that substantially have a ray-optical effect, reflect or refract incident light achromatically and unlike a diffraction grating without color splitting or interfering diffraction reflections.

[0009] The facets are preferably formed by planar surface pieces, which are each characterized by an inclination to the plane of the surface region and an azimuth angle.

[0010] In an advantageous variant of the invention, the facets are at least partially designed as reflective facets. The facets can also advantageously be designed at least partially as transmitting facets with a refractive effect. Reflective and transmitting facets can also be combined in a security element or semi-transparent facets can be present.

[0011] The facets are preferably arranged irregularly in the surface region, for example according to a pseudo-random number distribution. Pseudo-random numbers are sequences of numbers that appear random but are calculated using a deterministic algorithm and are therefore not true random numbers in the strictest sense. Nevertheless, pseudo-random numbers are widely used because the statistical properties of a pseudo-random number distribution, such as the equal probability of individual numbers or the statistical independence of successive numbers, are usually sufficient for practical purposes, and pseudo-random numbers are easy to generate with computers, in contrast to true random numbers. A pseudo-random number distribution is always aperiodic in the sense of the present application, since in

a pseudo-random number distribution there is no fixed, constant distance ("period") between successive values.

[0012] According to an advantageous variant of the invention, the facets are arranged with the same shape and size in the surface region. Alternatively, the facets are arranged with varying shape and/or size in the surface region, wherein the facets in the surface region are arranged in particular with an aperiodically or even irregularly varying shape and/or size. In an advantageous embodiment, the available surface region is completely covered with facets, so that the overlapping of the facets automatically results in different facet shapes and sizes.

[0013] The facets advantageously have a maximum extension in the plane of the surface region, which is between 2 μm and 30 μm , in particular between 5 μm and 15 μm . In the plane of the surface region, the facets advantageously have a minimum extension of 2 μm or more, in particular 5 μm or more.

[0014] The facets can be provided with various types of coatings, for example the facets can be, at least in sections, provided with a reflective and/or colored or color-shifting coating, in particular a coating with an interference system consisting of absorber, dielectric and reflector. The reflective coating can be formed, for example, by a reflective, opaque metal layer or by a thin or gridded semi-transparent metallic coating. The color-shifting coating is preferably by a thin-film element with a reflection layer, an absorber layer and a dielectric spacer layer arranged between the reflection layer and the absorber layer or by a thin-film element with two absorber layers and a dielectric spacer layer arranged between the two absorber layers. Finally, a highly diffractive dielectric coating or a coating made of a cholesteric liquid crystal layer may be considered.

[0015] In an advantageous configuration, the optically variable surface pattern generates a hidden piece of image information that cannot be detected by a viewer without aids. The optically variable surface pattern can also be combined with a further security feature, in particular with an openly visible security feature, such as a hologram or an optically variable saw tooth grating representation. The latter is particularly useful when the optically variable surface pattern itself generates a hidden piece of image information.

[0016] In a refinement of the invention, the optically variable surface pattern contains several sub-ranges that show different representations. The security element itself is, with particular advantage, a projection security element that projects the different representations onto a collecting surface with directed, parallel lighting. The collecting surface can be, for example, a screen or a matt screen and can be both planar and curved.

[0017] The invention also contains a data carrier, in particular a security paper or value document, with a security element of the type described. The data carrier can in particular be a value document, such as a banknote, in particular a paper banknote, a polymer banknote or a film composite banknote, but also an identification card, such as a credit card, a bank card, a cash payment card, an authorization card, an identity card or a passport personalization page.

[0018] The invention further relates to an embossing mold for generating an embossing structure, with a preferably metallic main body, which contains an optically variable surface pattern in a surface region, which shows different representations with different lighting and/or viewing directions, the optically variable surface pattern being formed of a plurality of facets that substantially have a ray-optical effect, the dimensions of which are smaller than 30 μm in at least one direction of the plane of the surface region, and which are arranged aperiodically in the plane of the surface region.

[0019] The embossing mold usually represents the negative form of the surface pattern desired in the embossing structure. Using the embossing mold, the desired target substrate, for example a thermoplastic or UV-curable lacquer layer applied to a film, is embossed and thus provided with the desired surface pattern. Corresponding methods are known to those skilled in the art and are described in the prior art.

[0020] The invention further relates to a method for producing a security element for securing security papers, value documents and other data carriers, wherein a substrate is provided and the substrate is provided with an optically variable surface pattern in a surface region, which shows different representations with different lighting and/or viewing directions, the optically variable surface pattern being formed of a plurality of facets that substantially have a ray-optical effect, the dimensions of which are smaller than 30 μm in at least one direction of the plane of the surface region, and which are arranged aperiodically in the plane of the surface region.

[0021] The methods known from the prior art, for example optical lithography or electron beam lithography, can be used for production.

[0022] Further exemplary embodiments and advantages of the invention are explained below with reference to the figures, which are not reproduced to scale and proportions in order to increase clarity.

[0023] In the figures:

[0024] Fig. 1 shows a schematic representation of a banknote according to an exemplary embodiment of the invention,

[0025] Fig. 2 shows schematically a cross section of a security element according to the invention,

[0026] Fig. 3 shows a way of producing a security element according to the invention, where (a) shows the geometry when projecting the representations of a projection security element and the desired representations, (b) shows the facets determined for the three image points of (a), and (c) shows a possibility of aperiodically filling the surface region with facets,

[0027] Fig. 4 shows another possibility of aperiodically filling the surface region with facets,

[0028] Fig. 5 shows facets for covering the surface region with different outline shapes,

[0029] Fig. 6 shows a security element according to the invention with transparent facets, and

[0030] Fig. 7 shows in (a) to (c) different projection geometries in reflection and transmission.

[0031] The invention will now be explained using the example of security elements for banknotes. Fig. 1 shows a schematic representation of a banknote 10, which is provided with two security elements 12 and 14 according to the invention. The first security element represents a security thread 12, which emerges from certain window areas on the surface of banknote 10, while it is embedded in the intermediate areas inside banknote 10. The second security element is formed by a glued-on transfer element 14 of any shape.

[0032] Security element 14 contains an openly visible piece of image information, in the exemplary embodiment a hologram 16, which represents the denomination "10" of the banknote. The security element further contains a hidden piece of image information located in background area 18 of hologram 16, which cannot be seen under normal lighting and is only projected onto a suitably placed screen or matt screen when the security element is illuminated in parallel, for example with a laser beam.

[0033] In other configurations, the security element 14 can also be designed in the form of a cover film which is arranged over a window area or a continuous opening of the banknote. The security element can be designed for viewing from above, through, or for viewing both from above and through.

[0034] For further explanation, Fig. 2 shows schematically a security element 20 according to the invention in cross section. The security element 20 has a substrate 22, which contains an optically variable surface pattern 26 in a surface region 24, which consists of a plurality of reflecting facets 28 which substantially have a ray-optical effect. Facets 28 are formed by planar surface pieces and are each characterized by their shape, size and orientation. The orientation of a facet 28 is indicated by the inclination α to plane 30 of the surface region and by an azimuth angle θ in plane 30. The azimuth angle θ is the angle between the projection of the normal vector of facet 28 onto plane 30 and a reference direction R.

[0035] In the exemplary embodiment, facets 28 have a rectangular shape and adjoin one another without any space between them. The size of facets 28 is different, with the side lengths of rectangular facets 28 projected into plane 30 being between 5 μm and 15 μm . Since the dimensions of facets 28 are thus far above the wavelength of visible light, it is ensured that the reflection of facets 28 is not based on optical diffraction effects, but substantially on ray-optical effects. Facets 28 thus reflect incident light 40 achromatically and other than a diffraction grating without color splitting. With a periodic arrangement of corresponding facets, for example on a square grid with a period of 10 μm , the projection would be overlaid by a corresponding grating diffraction image with very sharp reflections. These grating reflections can dominate the projection to such an extent that the actual desired representation can hardly be recognized.

[0036] As shown in Fig. 2, each of facets 28 reflects the incident light 40 like a small mirror in only a single direction 42, which is defined by the orientation of respective facet 28. This property of optically variable surface pattern 26 is in contrast to the properties of symmetrical diffraction gratings, in which perpendicularly incident light 40 is diffracted symmetrically into a plus first and minus first order of diffraction, so that in addition to a direct image formed in the direction of the plus first order of diffraction in the direction of minus the first order of diffraction, a further, conjugate image always arises.

[0037] In contrast, with the light reflection based on ray-optical effects on facets 28, no conjugate image is generated, so that optically variable surface pattern 26 not only reflects achromatically, but also typically shows different representations from opposite viewing directions.

[0038] For many applications, such as for security elements on thin film strips, it is desirable to design facets 28 with the smallest possible lateral dimensions, for example in order to achieve a low structural height at given inclination angles $\alpha \leq \alpha_{\max}$. In the context of the invention, facets 28 have a lateral dimension of less than 30 μm in at least one direction of plane 30. In some configurations, even smaller dimensions, for example $\leq 20 \mu\text{m}$, $\leq 15 \mu\text{m}$ or $\leq 10 \mu\text{m}$, may be desired or required. The aperiodic arrangement of facets 28 in surface region 24 according to the invention ensures, despite the small dimensions of facets 28, that no diffraction pattern is superimposed on the representation of the security element by a regular grid arrangement of small facets.

[0039] While in a periodic arrangement the facets are arranged on the grid points of a regular grating grid, in an aperiodic arrangement there is no simple, regular connection between the positions of neighboring facets. This reliably prevents constructive interference of the light reflected on neighboring facets and thus the creation of a superimposed diffraction pattern.

[0040] A way to produce a security element 50 according to the invention based on desired representations 66 will now be explained in more detail using the exemplary embodiment in Fig. 3.

[0041] Fig. 3(a) first shows the geometry when projecting the representations of a projection security element 50, which contains an optically variable surface pattern according to the

invention in a surface region 52. Incident parallel light 70, for example from a laser pointer, falls through an opening 64 in a matt screen 60 onto projection security element 50. The reflective facet arrangement of surface region 52 projects an asymmetrical image 66 onto matt screen 60, which in the exemplary embodiment consists of only three image points 62-1, 62-2 and 62-3 for the sake of illustration. Since the incident light 70 is only reflected in certain spatial directions, the facet arrangement shows different representations in different viewing directions.

[0042] Facets 54 of the surface region 52 are now formed from planar surface pieces, the orientation of which is given by an inclination to the plane of surface region 52 and an azimuth angle. From the desired position of the three image points 62-1 to 62-3 on matt screen 60, three orientations of associated facets 54-1 to 54-3 are determined so that these facets reflect perpendicularly incident light 70 in the direction of image points 62-1 to 62-3.

[0043] Each of these facets 54-1 to 54-3 is shown in top view in Fig. 3(b), with arrows 56-1 to 56-3 indicating the direction in which the facet deflects perpendicularly incident light. For example, the facet 54-1 rises from the edge 58 to the edge 59, so that perpendicularly incident light 70 is deflected in the direction of the arrow 56-1 and thus in the direction of the image point 62-1. The same applies to facets 54-2 and 54-3.

[0044] The inclination of facet 54-1 is now chosen so that the inclination angle α corresponds to half the angle between incident beam 70 and beam 72-1 directed towards image point 62-1. With vertical illumination 70, each facet 54-1 then contributes to the creation of image point 62-1 on matt screen 60. Accordingly, the inclination and azimuth angle of facets 54-2 and 54-3 are chosen so that the reflected rays contribute to the creation of image points 62-2 and 62-3 on matt screen 60.

[0045] As can be seen from Figs. 3(a) and (b), the azimuth angle of facet 54-3 with respect to reference direction R is just $\theta = 45^\circ$, the azimuth angle of facet 54-2 is $\theta = 90^\circ$ and the azimuth angle of facet 54-1 is $\theta = 180^\circ$. The inclinations of the two facets 54-1 and 54-2 are the same size and in the exemplary embodiment are $\alpha = 10^\circ$, while the inclination of facet 54-3, which is assigned to image point 62-3 further away from opening 64, is just under 15° .

[0046] In order, on the one hand, to obtain facets with small dimensions and therefore also small structural heights, and, on the other hand, to be able to generate an image 66 of great

brightness, entire surface region 52 of security element 50 is filled with facets 54-1 to 54-3, wherein the facets 54, as explained above, can be arranged aperiodically in order to avoid undesirable superimposition of image 66 with diffraction patterns.

[0047] One possibility of aperiodically filling surface region 52 with facets 54 is illustrated in Fig. 3(c). In the detail shown, surface region 52 is irregularly divided into rectangular tiles 58, the size (x, y) of which is each (a•d, b•d), where d = 5 µm and a and b independently of one another are each equal to 1, 2 or 3. The smallest possible tile has a size of 5 µm × 5 µm (a = b = 1), so that achromatic reflection is ensured. The largest possible tile has a size of 15 µm × 15 µm (a = b = 3), so that the structural height of the associated facets 54 is limited to $h_{\max} = 15 \mu\text{m} \cdot \sin\alpha_{\max}$ at a maximum inclination angle $\alpha_{\max}$. If the maximum inclination angle $\alpha_{\max}$ is, for example, 15°, corresponding to a maximum deflection of 30°, the structural height of the facets is limited to $h_{\max} = 3.9 \mu\text{m}$, which enables smooth production of the facet arrangement using embossing techniques.

[0048] Tiles 58 are now assigned one of the three facets 54-1 to 54-3 irregularly, for example according to a pseudo-random number distribution, as indicated by the corresponding directional arrows in Fig. 3(c). In this way, an irregular and aperiodic distribution of facets 54 is created in surface region 52, so that desired image 66 is projected onto matt screen 60 when illuminated 70 without interfering color splits or superimposed diffraction patterns.

[0049] Fig. 4 illustrates another possibility of filling surface region 52 aperiodically with facets 54. Not only the position but also the shape of facets 54 varies in an irregular and therefore aperiodic manner. When selecting the irregular shapes, care is taken to ensure that no sub-ranges with dimensions of less than 2 µm are created. The reason for choosing facet dimensions that are not too small is, in particular, that a light beam reflected at the facets is expanded due to diffraction. Halving the facet size causes the expansion angle to double, so that the resolution of the projected image becomes worse by a factor of 2. Very small facets therefore only produce faint, blurry image points.

[0050] In principle, the shape of the facets can be chosen arbitrarily. In addition to the configurations already mentioned with a rectangular outline (Fig. 3(c)) and irregular outline (Fig. 4), the facets can, for example, also be designed with a round outline 80, with an oval outline 82, with a triangular outline 84 or with a polygonal outline 86, as shown in Fig. 5.

[0051] The shape of the facets can also be chosen such that their lateral dimension is significantly larger in one direction than in the lateral direction perpendicular thereto. This can result in different diffraction-related resolution properties in two spatial directions, which can be advantageous in specific cases. A facet can be very long, especially in the direction in which it does not rise. This means that the corresponding reflex in the projection is hardly expanded in one direction, while the height of the facet is still advantageously small.

[0052] The shape of facets 54 can also represent a further hidden security feature that is only revealed to an inspector using an aid, for example a light microscope or a strong magnifying glass. For example, in a security element for ID documents, the same image 66 can be generated by facets with different outlines, as shown in Figs. 3(c), 4 and 5. The facet shape used can, for example, vary depending on the year of issue, region of issue, serial number or a specific group of people and thus form another hidden authenticity feature.

[0053] In addition to the reflective facets described so far, a security element 90 according to the invention can also have transparent facets 92, as illustrated in Fig. 6. Facets 92 at the interface of two media 94, 96 with different refractive index refract the incident light 100 in different directions 102 and thus allow the projection of an image in transmission. Fig. 6 shows an example of the deflection of incident light rays 100 by facets 92 at the interface of two media 94, 96 with refractive indices n_1 and n_2 . The difference in refractive indices $\Delta = |n_1 - n_2|$ is advantageously at least 0.3 or more, in particular 0.5 or more. One of the two media 94, 96 can also be air.

[0054] In addition to the configurations described so far, in which the projection image is projected onto a radiated matt screen, other projection geometries can also be considered according to the invention. To illustrate, Fig. 7(a) first shows the geometry of Fig. 3(a) again when reconstructing the representations of a security element 110 according to the invention. When illuminated, security element 110 projects a more complex image 114 in the form of a lettering "ECHT" composed of a plurality of image points onto matt screen 60.

[0055] Security element 110 also contains openly visible image information, namely a hologram 116 that represents the value "10". Surface region 112 with the optically variable surface pattern forms the background of hologram 116. Under normal lighting, the lettering "ECHT" is not

visible; rather, surface region 112 appears inconspicuously as a white background. Only when illuminated with the directed light of a laser pointer the lettering "ECHT" is projected onto a matt screen 60 as hidden image information. It is particularly advantageous for such hidden image information that it does not reveal its presence through a diffraction pattern or color splitting, which would typically be the case with a regular arrangement of facets or a grating structure with optical diffraction effect.

[0056] Two further projection geometries according to the invention are illustrated in Fig. 7(b). The optically variable surface pattern of security element 120 shown is designed so that reflection 124 takes place on a preselected side when illumination 122 is vertical, so that projection image 114 can be captured on a screen 126 next to security element 120. The surface pattern can also be designed in such a way that projection image 114 is only created on screen 126 when lighting 128 is at an angle.

[0057] Finally, Fig. 7(c) illustrates the generation of a projection image 114 in case of a transmitting security element 130, as described in connection with Fig. 6.

[0058] In a refinement, a security element according to the invention can also contain several areas that project different representations. Moving the readout beam over such a security element, changing projected representations are obtained. In addition to a simple change from a motif A to a motif B, complex kinematic effects can also be achieved using a plurality of different motifs.

[0059] Another special feature of security elements according to the invention is that the shape of the projected representation is independent of the wavelength or color of the light used. In the case of known security elements, in which the representations are generated by grating structures that have an optical diffraction effect, the shape and size of the representations, on the other hand, always depend on the wavelength of light. A diffractive projection element calculated for a red laser then projects a differently scaled, possibly even distorted image with a blue laser. In contrast, the representations of the security elements according to the invention are independent of the wavelength used.

[0060] This property represents a further significant improvement in counterfeit protection, as it cannot be reproduced even with asymmetrical diffraction gratings. To check this property, for

example, two representations projected with two different colors can be compared visually or mechanically, or the projection can be carried out with white light. Another advantage over diffractive projection elements is the greater brightness of the projections. Reflective facets can in principle reflect all incident light in a desired projection direction, while symmetrical diffraction gratings can project a maximum of half of the incident light intensity into the direct image.

[0061] The security element according to the invention can be designed as a homogeneous security thread, advantageously with additional features such as negative writing or magnetic properties. The security element can also form a security feature on a security strip or be used in combination with other optically variable elements, such as holograms or saw tooth grating depictions.

[0062] In particular, the optically variable surface pattern according to the invention can be present as a homogeneous surface that is inconspicuous when viewed normally and can be integrated into other representations, for example as a background representation, as a design element that appears white. The optically variable surface pattern according to the invention can also be nested with other representations, such as 3D representations, tilt images or the like.

[0063] While the invention has been described primarily using the example of projection security elements, the invention is not limited to such configurations. Rather, other optically variable representations can also be generated with the facet arrangements according to the invention. For example, flip images can be generated that have two or more areas with differently oriented facets that light up brightly from different viewing directions, as described in publications EP 0 868 313 B1 and EP 1 397 259 B1 for grating structures that have an optical diffraction effect. Kinematic effects, such as those described in the publications EP 0 868 313 B1 and WO 2007/079851, can also be generated with the optically variable surface patterns according to the invention. The disclosure of the publications mentioned is included in the present description.

List of reference numerals

10	banknote
12, 14	security elements
16	hologram

18	background area
20	security element
22	substrate
24	surface region
26	optically variable surface pattern
28	facets
30	plane of the surface region
40 incident	light
42	reflected light
50	security element
52	surface region
54	facets
54-1, 54-2, 54-3	facets
56-1, 56-2, 56-3	directions
58	tiles
60	focusing screen
62-1, 62-2, 62-3	image points
64	opening
66	image
70	incident light
72-1, 72-3	beam directed towards the image point
80, 82, 84, 86	outlines
90	security element
92	transparent facets
94, 96	media
100	incident light
102	directions
110	security element
112	surface region
114	image
116	hologram
120	security element
122	vertical lighting
124	reflection

126	screen
128	oblique lighting

CITATIONS INCLUDED IN THE DESCRIPTION

This list of the documents listed by the applicant has been generated automatically and is included for a better understanding of the reader only. The list is not part of the German patent or utility model application. DPMA cannot be held responsible for any errors or omissions.

Cited patent literature

- WO 2005/038499 A2 [0002]
- EP 0762238 A1 [0005]
- EP 0868313 B1 [0063, 0063]
- EP 1397259 B1 [0063]
- WO 2007/079851 [0063]

Claims

1. A security element for security papers, value documents and other data carriers, with a substrate which contains an optically variable surface pattern in a surface region, which shows different representations with different lighting and/or viewing directions, the optically variable surface pattern being formed of a plurality of facets that substantially have a ray-optical effect, the dimensions of which are smaller than 30 μm in at least one direction of the plane of the surface region, and which are arranged aperiodically in the plane of the surface region.
2. The security element according to claim 1, characterized in that the facets are formed by planar surface pieces, which are each characterized by an inclination to the plane of the surface region and an azimuth angle.
3. The security element according to claim 1 or 2, characterized in that the facets are at least partially designed as reflective facets.
4. The security element according to at least one of claims 1 to 3, characterized in that the facets are at least partially designed as transmitting facets with a refractive effect.
5. The security element according to at least one of claims 1 to 4, characterized in that the facets are arranged irregularly in the plane of the surface region.
6. The security element according to at least one of claims 1 to 5, characterized in that the facets are arranged with the same shape and size in the plane of the surface region.
7. The security element according to at least one of claims 1 to 5, characterized in that the facets are arranged in the plane of the surface region with varying shape and/or size, in particular that the facets are arranged with aperiodically or even irregularly varying shape and/or size in the surface region.
8. The security element according to at least one of claims 1 to 7, characterized in that the facets have a maximum extension in the plane of the surface region, which is between 2 μm and 30 μm , in particular between 5 μm and 15 μm .

9. The security element according to at least one of claims 1 to 8, characterized in that the facets in the plane of the surface region have a minimum extension of 2 μm or more, in particular of 5 μm or more.
10. The security element according to at least one of claims 1 to 9, characterized in that the facets are, at least in sections, provided with a reflective and/or colored or color-shifting coating, in particular a coating with an interference system consisting of absorber, dielectric and reflector.
11. The security element according to at least one of claims 1 to 10, characterized in that the optically variable surface pattern generates a hidden piece of image information that cannot be detected without aids.
12. The security element according to at least one of claims 1 to 11, characterized in that the optically variable surface pattern is combined with a further security feature, in particular with an openly visible security feature, such as a hologram or an optically variable saw tooth grating representation.
13. The security element according to at least one of claims 1 to 12, characterized in that the optically variable surface pattern contains several sub-ranges which show different representations.
14. The security element according to at least one of claims 1 to 13, characterized in that the security element is a projection security element which projects the different representations onto a collecting surface with directed, parallel lighting.
15. A data carrier with a security element according to at least one of claims 1 to 14.
16. The data carrier according to claim 15, characterized in that the data carrier is a value document, such as a banknote, in particular a paper banknote, a polymer banknote, a film composite banknote or a certificate, a passport or an identity card.

17. An embossing mold for generating an embossing structure, with a main body which contains an optically variable surface pattern in a surface region, which shows different representations with different lighting and/or viewing directions, the optically variable surface pattern being formed of a plurality of facets that substantially have a ray-optical effect, the dimensions of which are smaller than 30 μm in at least one direction of the plane of the surface region, and which are arranged aperiodically in the plane of the surface region.

18. A method for producing a security element for securing security papers, value documents and other data carriers, wherein a substrate is provided and the substrate is provided with an optically variable surface pattern in a surface region, which shows different representations with different lighting and/or viewing directions, the optically variable surface pattern being formed of a plurality of facets that substantially have a ray-optical effect, the dimensions of which are smaller than 30 μm in at least one direction of the plane of the surface region, and which are arranged aperiodically in the plane of the surface region.

4 sheets with drawings to follow