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(54) Bezeichnung: OPTISCH VARIABLES SICHERHEITSELEMENT

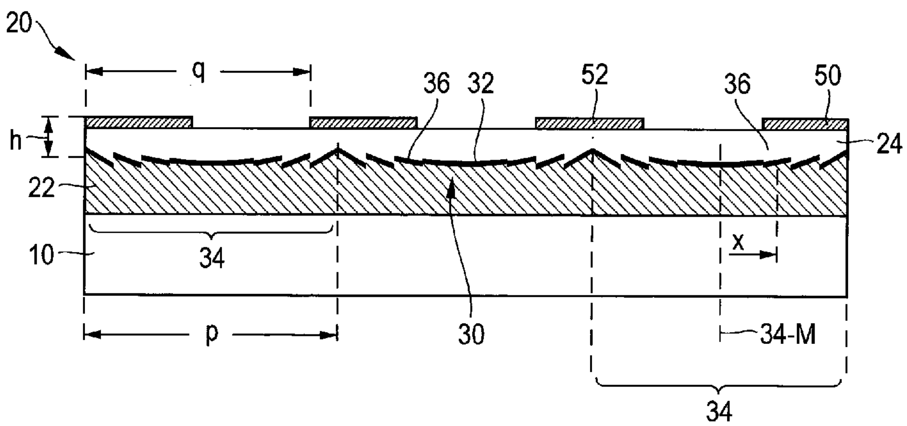

Fig. 2

(57) Abstract: The invention relates to an optically variable security element (20) for protecting objects of value, comprising a one- or two-dimensional relief pattern (30) formed by a plurality of pattern elements (34) and having a first pattern width p below 500 µm in at least one spatial direction, and wherein the pattern elements (34) are each formed by at least two relief elements (36) reflecting in different directions, and comprising at least one dot and/or line pattern (50) arranged vertically above or below the relief pattern (30), and having a second pattern width q in said spatial direction, wherein the second pattern width q only differs slightly from the first pattern width p, in particular by less than a fifth, and/or the first pattern width p and/or the second pattern width q is modulated in a position-dependent manner such that, a movement effect occurs via the cooperation of the relief pattern (30) and the dot and/or line pattern (50) with the tilting of the security element (20), and wherein the vertical distance (h) of the relief pattern (30) and the dot and/ or line pattern (50) is less than half the pattern width p.

(57) Zusammenfassung: Die Erfindung betrifft ein optisch variables Sicherheitselement (20) zur Absicherung von Wertgegenständen, mit - einem ein- oder zweidimensionalen Reliefraster (30) aus einer Mehrzahl von Rasterelementen (34), welches in zumindest einer Raumrichtung eine erste Rasterweite p unterhalb von 500 µm aufweist, und bei dem die Rasterelemente (34) jeweils aus zumindest zwei, in unterschiedliche Richtungen gerichtet reflektierenden Reliefelementen (36) gebildet sind, und - mit zumindest einem Punkt- und/ oder Linienraster (50), das vertikal über oder unter dem Reliefraster (30) angeordnet ist, und in der genannten Raumrichtung eine zweite

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Erklärungen gemäß Regel 4.17:

— *hinsichtlich der Berechtigung des Anmelders, ein Patent zu beantragen und zu erhalten (Regel 4.17 Ziffer ii)*

Veröffentlicht:

— *mit internationalem Recherchenbericht (Artikel 21 Absatz 3)*

Rasterweite q aufweist, wobei sich die zweite Rasterweite q von der ersten Rasterweite p nur geringfügig, insbesondere um weniger als ein Fünftel unterscheidet, und/oder die erste Rasterweite p und/ oder die zweite Rasterweite q ortsabhängig moduliert sind, so dass durch das Zusammenwirken des Reliefrasters (30) und des Punkt- und/oder Linienrasters (50) beim Kippen des Sicherheitselements (20) ein Bewegungseffekt entsteht, - und wobei der vertikale Abstand (h) von Reliefraster (30) und Punkt- und/oder Linienraster (50) weniger als die halbe Rasterweite p beträgt.

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Optically Variable Security Element

The present invention relates to an optically variable security element for securing valuable articles. The present invention also relates to a method for manufacturing such a security element, as well as a data carrier that is equipped accordingly.

For protection, data carriers, such as value or identification documents, or other valuable articles, such as branded articles, are often provided with security elements that permit the authenticity of the data carriers to be verified, and that simultaneously serve as protection against unauthorized reproduction.

Security elements having viewing-angle-dependent effects play a special role in safeguarding authenticity, as these cannot be reproduced even with the most modern copiers. Here, the security elements are furnished with optically variable elements that, from different viewing angles, convey to the viewer a different image impression and, depending on the viewing angle, display for example a different color or brightness impression and/or a different graphic motif.

Here, both in security printing and in packaging printing, colored and dynamic human features that are easy to verify are of particular interest. Currently, such features are realized primarily through holograms and hologram-like designs, but these place considerable technological demands on the manufacturing process and thus cannot be used economically for all applications.

Proceeding from this, it is the object of an embodiment of the present invention to specify an optically variable security element of the kind cited above that avoids the disadvantages of the background art. In particular, the object is to provide a security element that is easy and economical to manufacture, that, when tilted, displays visually appealing movement effects, and that, ideally, also has a small thickness and is thus well suited for application to banknotes and other value documents.

Said object is solved by the features of the independent claims. Developments of the present invention are the subject of the dependent claims.

The present invention includes an optically variable security element for securing valuable articles, having

- a one- or two-dimensional relief grid that is composed of a plurality of grid elements and that has a first line screen p below 500 µm in at least one spatial direction and in which the grid elements are each formed from at least two relief elements that are directionally reflective in different directions, and

- having at least one dot and/or line grid that is arranged vertically above or below the relief grid, and has a second line screen q in said spatial direction, the second line screen q differing only slightly from the first line screen p, namely by less than one-fifth, and/or the first line screen p and/or the second line screen q being location-dependently modulated such that a movement effect is created by the interplay of the relief grid and the line grid when the security element is tilted,

– and the vertical spacing between the relief grid and the dot and/or line grid being less than half the line screen p.

According to current understanding, the movement effect is created by a moiré effect between two grids of similar line screen, here the relief grid and the dot and/or line grid. Here, the line screens of the relief grid and the dot and/or line grid differ only slightly, especially by less than one-fifth. Alternatively or additionally, the line screen of one of the two grids or even of both grids is suitably location-dependently modulated. In the latter case, the line screen of the dot and/or line grid can, in principle, also be equal to the line screen of the relief grid, since the moiré effect is already created by the location-dependent modulation.

Below, for the sake of simplicity, often only "the dot and/or line grid" is mentioned instead of "the at least one dot and/or line grid", but it is understood that this is not intended to exclude the presence of more than one dot and/or line grid. The statements made then apply in each case for at least one, preferably even for all dot and/or line grids in the security element.

In particular, in the case of multiple dot and/or line grids, the line screens of the dot and/or line grids are preferably all chosen such that they differ only slightly from the first line screen p, especially by less than one-fifth, and/or the first line screen p and/or the second line screen q are location-dependently modulated in such a way that a movement effect is created by the interplay of the relief grid and the respective dot and/or line grid when the security element is tilted. If the relief grid is a two-dimensional relief grid that, in addition to the first line screen p, has a further line screen p' in a second spatial direction, then in the case of line grids, a second or further line grid can also have a line screen that, instead of from the first line screen p, differs only slightly from the further line screen p', especially by less than one-fifth, and/or is location-dependently modulated in such a way that a movement effect is created by the interplay of the relief grid and the respective line grid when the security element is tilted. In the case of a two-dimensional dot grid that, in addition to the first line screen q, has a further line screen q' in a second spatial direction, also the further line screen q' can differ only slightly from the further line screen p′ and/or one or both of the line screens p', q' can be location-dependently modulated in such a way that a movement effect is created by the interplay of the relief grid and the dot grid when the security element is tilted.

In one advantageous embodiment, at least one of the dot and/or line grids is developed as a line grid. In this case, preferably even all dot and/or line grids are developed as line grids.

The line screen p is advantageously even smaller than 400 µm and, in one advantageous embodiment, is between 200 µm and 400 µm, in another advantageous embodiment, between 60 µm and 200 µm. The second line screen q differs only slightly from the first line screen p, especially by less than one-fifth or even by less than one-tenth, especially by less than 15 µm. For other designs, however, for instance for use in branded objects or in packaging printing, the line screen p can also be larger than 400 µm.

In the case of a line grid, the line grid advantageously comprises a plurality of lines whose width is preferably between 5 µm and 200 µm, but in any case is smaller than half the line screen q. The line width is particularly preferably between 45 µm and 150 µm and especially between 50 µm and 120 µm.

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The lines can be unmodulated, that is, have a constant line width along their longitudinal dimension. But the line width can also change along the longitudinal dimension of the lines, especially increase or decrease, or can be modulated on one side or two sides. Here, the lines of the line grid can be materially present as a positive, for example as printed or metalized lines, but they can also be present material-free as a negative, that is, as a gap in a surrounding material region, for example as line-shaped gaps in a print image or a metalization. In the case of positive lines, the specified line widths refer to the widths of the material regions, and in the case of negative lines, to the widths of the material-free gap regions. An additional piece of information can be encoded in the security element by a change in the line width along the longitudinal dimension of the lines. The movement effect can be intensified by said additional piece of information, or even remain standing still, for instance in the case of a gap in the background.

The lines of a line grid can also include gap regions that are formed especially in the form of patterns, characters or a code. The gap regions are preferably arranged in the form of a grid that has, in one spatial direction, a line screen that does not differ from a line screen of the relief grid, or differs only slightly therefrom, especially by less than one-fifth.

In the case of a dot grid, the grid elements (dots) of the dot grid can have any arbitrary shape and especially be developed in the form of patterns, characters or a code. In particular, the grid elements themselves can consist of multiple dots, for example of different colors, or be resolved into such dots.

In one advantageous embodiment, at least one line grid is a print line grid that preferably is formed at least in a sub-region from a plurality of substantially parallel print lines having a spacing q. The sub-region can be developed in the form of a pattern, character or code. However, the print line grid can also be formed completely from parallel print lines. The print lines can especially be printed with a translucent ink to ensure a partial translucence of the line grid.

The print line grid(s) are advantageously separated from the relief grid by a spacing layer, the spacing layer preferably including an embossing lacquer layer in which the relief elements of the relief grid are embossed. The embossing lacquer layer is expediently developed to be clear transparent or colored transparent. The spacing layer can especially be formed by only the embossing lacquer layer, or can also be formed by a foil having an embossing lacquer layer present thereon.

The relief elements of the relief grid are advantageously provided with a reflection-increasing coating, especially a metalization. Here, the color impression of the metalization is preferably substantially metallic silver, such as in a metalization composed of aluminum or silver, but also the use of colored metals, such as copper or gold, may be considered. The coating can be opaque, but also semitransparent or even largely translucent, and then consist, for example, of a high-index layer composed of HRI (high-refractive-index) materials, for example composed of TiO_2 or ZnS. For the use of HRI materials, a dark background is advantageous.

In one advantageous embodiment, it is provided that at least one dot or line grid is formed by a reflection-increasing coating, present in dot or line grid form, of the relief elements of the relief grid. In the case of a line grid, the line grid then includes alternating coated and uncoated lines, so in the case of a metalization, metalized and demetalized lines. The uncoated line regions reveal the view of layers or information lying below the relief grid and thus permit an intelligent combination of the relief grid with a background design. Such a background design can be formed, for example, by an offset print layer or a nyloprint layer present on the substrate.

The relief grid is advantageously combined with a background layer, especially a contiguous ink layer, that lies below the reflection-increasing coating. The background layer appears in the uncoated dot and/or line regions and thus provides, perfectly registered with the relief grid, a dot and/or line grid having a coloring defined by the background layer. The background layer can also be multicolored and depict a pattern or other motif and can be imprinted or applied by an arbitrary other method. Furthermore, alternatively or in addition to the background layer, the relief grid can be combined with a colored transparent or translucent layer that lies above the reflection-increasing coating and that appears specifically in the uncoated dot and/or line regions. The coloring of the dot and/or line grid produced in this way in register with the relief grid is defined by the coloring of the transparent or translucent layer. In one preferred embodiment, the colored transparent layer is formed by the embossing lacquer layer. A colored embossing lacquer can determine the hue of the security element or modify it in the region of the embossing lacquer. Also a spot coating with two different-colored or colorless embossing lacquers is possible. For example, the embossing lacquer can be colored yellow in a first sub-region and be colorless in a second sub-region. If such an embossing lacquer layer is combined with a blue background, a first greenish sub-region (combination blue + yellow) and a second blue sub-region

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(combination blue + colorless) result in the security element in perfect register.

The small vertical spacing between the relief grid and the dot and/or line grid constitutes a significant advantage of security elements according to an embodiment of the present invention. Since the movement effect is created by a moiré effect between two similar grids, here the relief grid and the dot and/or line grid, no minimum spacing need be maintained between the two grids, unlike, for example, with focusing-lens or mirror arrangements. The vertical spacing between the relief grid and the point or line grid is thus advantageously less than one-fifth, especially even less than one-tenth of the line screen p, and is usually below 20 µm, in some cases even below 10 µm or even below 5 µm. In the extreme case, the vertical spacing can even be zero, specifically if the dot and/or line grid is developed in the reflection-increasing coating of the relief grid and is thus arranged immediately thereon without any gap.

In one advantageous variant of the present invention, the relief grid is a one-dimensional grid composed of a plurality of elongated grid elements that has said line screen p. Here, the grid elements are each advantageously composed of at least two line-type relief elements that are directionally reflective in different directions. In particular, the grid elements are each formed from a plurality of line-type micromirrors, from a cylindrical Fresnel mirror structure or from other, preferably achromatically reflective diffractive structures.

In another, likewise advantageous variant of the present invention, the relief grid is a two-dimensional grid composed of a plurality of grid elements that has said line screen p in a first spatial direction. As the two-dimensional grid, in addition to the first line screen p, the relief grid has in a second spatial direction a further line screen p' that is not necessarily, but advantageously, likewise below 500 µm, especially below 400 µm. In one advantageous design, the first line screen p and the further line screen p' are identical, such that the grid elements can be developed to be square or spherical. However, the first line screen p and the further line screen p' can also differ, preferably by a factor between 1.5 and 5, and form a grid having rectangular or elliptical grid elements.

The grid elements of a two-dimensional grid are advantageously each formed from at least two, preferably at least three, particularly preferably at least four relief elements that are each directionally reflective in different directions and are especially each formed from a circular or elliptical arrangement of a plurality of micromirrors, from a spherical or elliptical Fresnel mirror structure or from other, preferably achromatically reflective diffractive structures. The relief elements can especially themselves be arranged like a grid within a grid element, for example n*m relief elements (n, m integers ≥ 2) in the form of an n x m grid.

In one advantageous development, the grid elements are arranged having a motif-shaped contour and spaced apart from one another. The grid elements can especially be developed having a simple geometric contour, for example circle, rectangle, ellipse, star and the like, or can also form a more complex motif, such as a crest, a cloud pattern, a blossom or the like.

The grid elements are advantageously each formed from a plurality of relief elements that are directionally reflective in different directions, especially in a one-dimensional grid from at least 10 line-type relief elements that are directionally reflective in different directions, and in a two-dimensional grid, from at least 10 x 10 relief elements that are directionally reflective in different directions.

The reflective relief elements especially comprise one or more reflection surfaces that can be planar or curved, the relief elements in the former case typically being referred to as micromirrors, while in the latter case, they typically form a zone of a Fresnel mirror structure. Here, the reflective relief elements of each grid element are advantageously arranged and developed in such a way that the grid element produces the reflection behavior of a concave or convex curvature. For this, the individual relief elements can be arranged, for example, next to one another with increasing or decreasing slope of their reflection surface(s), such that, in each case, they locally reproduce the slope of a concave or convex curvature. For two-dimensional relief grids, the slopes of the reflection surfaces can reproduce a concave or convex curvature in two spatial directions. Alternatively, the slopes of the reflection surfaces reproduce a concave or convex curvature only in one spatial direction, while they are oriented irregularly or randomly in the other spatial direction.

The grid elements of the relief grid can all be developed to be homogeneous, that is, all formed having the same arrangement of relief elements. Alternatively, the relief grid can also include two or more different grid elements that preferably each produce different movement effects when the security element is tilted. For example, the relief grid can include first grid elements that produce the reflection behavior of a concave curvature, and second grid elements that produce the reflection behavior of a convex curvature. The lines produced by the first and second grid elements then move due to the different curvature when the security element is tilted in opposite directions. As a result, also the lines of a moiré line pattern produced in interplay with a dot and/or line grid migrate in opposite directions.

The relief grid can occupy the entire area of the security element, but can also be present only in sub-regions of the security element, especially in the form of patterns, characters or a code.

The dot and/or line grid advantageously comprises a plurality of parallel lines that run substantially perpendicular to said first spatial direction. The lines of further line grids can likewise run substantially perpendicular, but also substantially parallel to the first spatial direction.

As already mentioned above, also two or more dot and/or line grids arranged vertically above or below the relief grid can be provided in the security element. Here, the directions above and below refer to the direction to the viewer. An element that is closer to the viewer lies "above" an element that is further away, which is, accordingly, "below" the former element. If multiple dot and/or line grids are provided, advantageously, at least one dot and/or line grid is arranged above the relief grid. The multiple dot and/or line grids can also all be arranged above the relief grid and are especially in register with one another. Multiple dot and/or line grids are advantageously present in different, especially contrasting colors. They can be present in nearly congruent regions, in partially overlapping regions or also in regions that are separated from one another.

In another advantageous design, at least one dot and/or line grid is arranged above the relief grid and at least one dot and/or line grid below it. In this way, two-sided security elements can be realized that can be viewed from two opposing sides and that each display a movement effect. Such two-sided security elements can, for example, be introduced into a data carrier in the form of a pendulum security thread or be arranged over a window region or a hole in a data carrier.

In advantageous designs, either the first line screen p is fixed and the second line screen q is location-dependently modulated, or the second line screen q is fixed and the first line screen p is location-dependently modulated. Here, it can especially be provided that the first line screen p varies locally with a fixed second line screen q. The grid elements themselves here are advantageously all developed to be homogeneous. A similar effect can be achieved when the first line screen p is fixed but the curvature or the slope of the relief elements that form the grid element varies locally.

A location-dependent modulation of the relief grid can also be produced in that elliptical or circular micromirror arrangements or cylindrical, elliptical or circular Fresnel mirror structures having a location-dependent focal-point shift are used. A controlled effect modulation can also be achieved in this way.

According to a preferred development of the present invention, the first and/or second line screen is location-dependently modulated in that the positions of the grid elements of the relief grid or of the dot and/or line grid are given by a phase function $\phi(x,y)$ that depends on the position (x,y) of the grid element in the security element and whose function value indicates the deviation of the position of the grid element from the position of a grid point in a regular grid, normalized to the unit interval $[0,1]$, and the phase function $\phi(x,y)$ varying location dependently in such a way that a movement effect, especially a pump or rotation effect, is created when the security element is tilted.

In one advantageous embodiment, the phase function $\phi(x,y)$ depends directly, especially linearly, on the angle between the position (x,y) of the grid element and a fixed reference point (x_0, y_0) in the security element such that a rotation effect about the reference point (x_0, y_0) is created when the security element is tilted. In this case, the phase function is preferably given by

$$\phi(x,y) = \mathrm{mod}((\alpha + k^*\arg((x-x_0)+i(y-y_0))/(2\pi), 1)$$

with an integer $k \neq 0$ and an offset angle α, where mod(x,y) represents the modulo function and arg(z) the argument of a complex number. In the case of a line grid, when viewed, the visual impression of a windmill pattern having $|k|$ blades that rotates when tilted about the reference point is then produced, the sign of k describing the rotation direction of the blades when tilted.

Further concrete examples of advantageously usable phase functions and further details on phase functions can be found in document WO 2016/020066 A2, the disclosure of which is incorporated in the present application by reference.

Different phase functions especially permit different movement effects or also 3D effects to be achieved. Here, both the first line screen, that is, a line screen of the relief grid, and the second line screen, that is, a line screen of the dot and/or line grid, can be location-dependently modulated according to the phase function. If, for example, the security element is assumed to be a foil strip that includes a relief grid and is adhered to a banknote and, to produce a movement effect, is overprinted with a dot and/or line grid in offset printing, especially the following possibilities exist: M1) The relief grid on the foil strip is regular and the printed grid is location-dependently modulated according to a phase function, or M2) the relief grid on the foil strip is location-dependently modulated according to the phase function and the printed grid is regular.

In practice, both variants can be advantageous. In a first embodiment, there should result, for example, above the foil strip a movement effect in which, when tilted forward and backward, a bar pattern (fig. 1) runs in the opposite direction up or down the left or right half of the strip. If, for example, there are tolerances of ± 2 mm between the position of the foil strip and the print image, and if the print grid is offset according to the phase function, then, due to said tolerances, the boundary between the bars moving in opposite directions on the foil migrates up to 2 mm from the center of the foil strip (to the left or right), which can already stand out clearly. If, in contrast, the relief grid on the foil is modulated locally according to the phase function, then the movement effect remains in the center of the strip also when the print image migrates to the left or right relative to the strip. Thus, for this design, a regular print grid and a relief grid modulated according to the phase function are advantageous.

In a second embodiment, it may be desired, for example, that, when tilted forward and backward, a bar pattern runs in the opposite direction to the left or right on the upper or lower half of the strip. If the relief grid here were to be modulated according to the phase function and the print grid arranged regularly, then the boundary between the bars (in the vertical direction) running in different directions (to the left or right) would, due to tolerances in the positioning of the print and the foil, run upward or downward within the overprinted region. In said embodiment, it is thus advantageous to work

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with a regular relief grid and to modulate the print grid locally according to the phase function. The transition between the different moving bars in the vertical direction is then namely, independently of the tolerances of the positioning of the two grids, always precisely in the middle of the overprinted region.

In some applications, it can also be advantageous to provide a location-dependent modulation by a phase function for both grids. Here, the desired total modulation $\phi(x,y)$ is broken down into two phase functions, $\phi_R(x,y)$ for the relief grid and $\phi_D(x,y)$ for the print grid, such that $\phi(x,y) = \phi_R(x,y) + \phi_D(x,y)$ applies. In this case, the tolerances of the positioning are particularly critical, but also result in particularly counterfeit-proof security elements. If it is presumed, for instance, that the security elements described here are provided on banknotes of different denominations, for example with a value of 10 (10er) and a value of 100 (100er) and assumed that a counterfeiter is familiar with the technology disclosed here and has access to the associated printing technology, then, in the event that both grids are completely regular, the counterfeiter could, in principle, remove the print grid from the security element of a 10er and, by executing an embodiment of the present invention, produce a security element of a 100er from the security element of the 10er. If, in contrast, the two grids are modulated with different phase functions, in addition, the counterfeiter would have to know the phase function of the relief grid in order to be able to generate an appropriate print grid. In this way, a simple adoption is not possible even with knowledge of the present invention.

The security element is advantageously a security thread, especially a window security thread or a pendulum security thread, a tear strip, a security band, a security strip, a patch or a label for application to a security paper, value document or the like.

An embodiment of the present invention also includes a data carrier having a security element of the kind described, in a preferred design, at least one line grid of the security element covering the relief grid in sub-regions and in sub-regions extending outside the relief grid to the data carrier provided with the security element. In this way, the security element is secured on the data carrier and integrated into its design. Any manipulation or even removal and transfer of the security element to another data carrier is not easily possible due to the required registration of said sub-regions. Here, the sub-region of the line grid that extends outside the relief grid to the data carrier advantageously appears as a halftone area.

In one advantageous embodiment, the security element is arranged in or over a window region or a through opening in the data carrier. Such an arrangement is advantageous especially in the described two-sided designs, in which one movement effect is visible in direct top view and another movement effect when viewed through the window region or the through opening.

The data carrier can especially be a value document, such as a banknote, especially a paper banknote, a polymer banknote or a foil composite banknote, a stock, a bond, a certificate, a voucher, a check, a valuable admission ticket, but also an identification card, such as a credit card, a bank card, a cash card, an authorization card, a personal identity card or a passport personalization page. The data carrier can also be a decorative item, such as packaging, fan merchandise or a clothing label, or also a package insert for drugs. If the data carrier is a foil element, said data carrier can also constitute a packaging foil that encases a further packaging.

The present invention further includes a method for manufacturing an optically variable security element of the kind described above, in which

- a one- or two-dimensional relief grid composed of a plurality of grid elements and at least one dot and/or line grid are vertically stacked one on top of the other,

- the relief grid being developed having a first line screen p below 500 µm in at least one spatial direction,

- the grid elements of the relief grid each being formed from at least two relief elements that are directionally reflective in different directions,

- the at least one dot and/or line grid being developed having a second line screen q in said spatial direction, the second line screen q differing only slightly from the first line screen p, namely by less than one-fifth, and/or the first line screen p and/or the second line screen q being location-dependently modulated such that a movement effect is created by the interplay of the relief grid and the line grid when the security element is tilted,

- and the vertical spacing between the relief grid and the dot and/or line grid being less than half the line screen p.

Here, to produce the relief grid, an embossing lacquer layer is advantageously applied to a carrier foil, embossed with a desired relief pattern and provided with a reflection-increasing coating, especially a metalization. In advantageous embodiments, the reflection-increasing coating is applied in the form of a dot and/or line grid, particularly preferably in the form of a line grid, or it is applied contiguously and then removed again in sub-regions to produce a reflection-increasing coating in the form of a dot and/or line grid, particularly preferably in the form of a line grid.

In one advantageous procedure, the relief grid is applied to a desired data carrier, for example a banknote, with an adhesive layer. Especially in two-sided security elements, the adhesive layer can be transparent, especially clear transparent or colored transparent. The carrier foil can remain in the layer structure but, in advantageous designs, is removed after application to keep the thickness of the security element small.

If the relief grid is combined with one or more print grids (dot and/or line grids), the print grids are advantageously applied in offset printing, in indirect offset printing, in flexo printing or in steel engraving. A print grid can be applied to the front and/or reverse of the security element especially in super-simultaneous printing. In one advantageous variant, the print grids are imprinted after the transfer of the relief grid to a data carrier and, if applicable, the removal of the carrier foil. In other advantageous designs, the security element is completed as a foil element having a relief grid and a print grid and applied to a data carrier as a finished security element or, such as in the case of a window or pendulum security thread, embedded in a data carrier.

In a currently particularly preferred variant, the at least one dot and/or line grid is produced in intaglio printing. This enables, in addition to a high print resolution, also a tactile detectability of the dot and/or line grid.

A combination of an intaglio printing color with a background color offers particular advantages, since in this way, visually attractive color gradients and colored edges can be produced within a motif. It is especially expedient to combine differently developed regions to accommodate the different resolutions of the printing methods (high resolution in intaglio printing, lower resolution in offset printing). For this, larger grid elements, for example, can be provided for the print in the background color and smaller grid elements for the print in the intaglio printing color. Specifically, the intaglio printing color can be provided, for example, in each case in a smaller inner field, while a larger outer field is printed on with the background color.

Said movement effect can especially display lines or bars, also having multiple line or bar patterns moving in opposite directions. The movements can, but need not be, rectilinear, but rather can, for example, also run in a curve and, in the case of multiple line or bar patterns, intertwined. As further movement effects, pump and rotation effects, for example, may be considered. All movement effects are preferably colored, especially multicolored.

Due to their small thickness, security elements according to and embodiment of the present invention are particularly well suited for application to banknotes and other value documents. To produce the relief grid, advantageously, a foil element can be used that includes embossed micromirrors. As a result, a significantly higher brilliance can be achieved compared with conventional micromirrors produced in steel engraving.

Furthermore, the use of small relief elements facilitates a high resolution of the relief grid. Further, the appearance and the viewing angle can be greatly influenced by the alignment of the relief elements, and good registration is possible between the region having a moiré effect and any further authenticating features of the security element.

Especially in the field of packaging, it can also be expedient that the relief grid and the dot and/or line grid are not firmly joined together, but rather are present on different packaging parts and only in a check position are stacked one on top of another with a vertical spacing of less than half the line screen.

Such an optically variable security arrangement serves to secure packaging and includes

– a securing means having a one- or two-dimensional relief grid that is composed of a plurality of grid elements, that has a first line screen p below 500 µm in at least one spatial direction, and in which the grid elements are each formed from at least two relief elements that are directionally reflective in different directions, and

– a verification means having at least one dot and/or line grid that has a second line screen q in said spatial direction,

– the securing means and the verification means being developed in such a way that, when the securing means and verification means are laid vertically on top of one another in a check position, the vertical spacing between the relief grid and the dot and/or line grid is less than half the line screen p, and

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- the second line screen q differing only slightly from the first line screen p, especially by less than one-fifth, and/or the first line screen p and/or the second line screen q being location-dependently modulated such that a movement effect is created due to the interplay of the relief grid and the dot and/or line grid when the security arrangement situated in the check position is tilted.

The further advantageous embodiments of the relief grid and the dot and/or line grid correspond to the advantageous embodiments of the grids in the described security element.

Suitable packaging especially comprises at least one packaging part that, in the desired check position, covers another packaging part. For example, two packaging parts can be telescoped, or one packaging part constitute a top for the other packaging part. One packaging part can also constitute an outer packaging foil or a sleeve for the other packaging part. Securing means and/or verification means can especially be present in a viewing window of the respective packaging part.

Further exemplary embodiments and advantages of the present invention are explained below by reference to the drawings, in which a depiction to scale and proportion was dispensed with in order to improve their clarity.

Shown are:

Fig. 1 a schematic diagram of a banknote having an optically variable security element according to an embodiment of the present invention,

Fig. 2 a security element according to an embodiment of the present invention, in cross section,

Fig. 3 to explain the creation of the fine line grid, in (a), only the relief grid of the security element in fig. 2, and in (b), the visual appearance of the relief grid in (a),

Fig. 4 a security element according to another exemplary embodiment of the present invention, in cross section,

Fig. 5 a security element according to a further exemplary embodiment of the present invention, in cross section,

Fig. 6 in (a), a top view of the relief grid of a security element according to the present invention, and in (b), a top view of the complete security element, in which the relief grid in (a) is combined with two print line grids,

Fig. 7 in (a) and (b), top views as in fig. 6 for a security element having a two-dimensional relief grid,

Fig. 8 in (a) and (b), top views as in fig. 6 and 7 for a security element having a two-dimensional relief grid having two different line screens,

Fig. 9, 10 Top views as in fig. 6(b), 7(b) and 8(b) for security elements according to further exemplary embodiments of the present invention,

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Fig. 11 a security element according to a further exemplary embodiment, in cross section,

Fig. 12 in (a), a top view of a further security element according to an embodiment of the present invention, and in (b) and (c), the appearance of the security element in (a) when viewed vertically or obliquely from above, and

Fig. 13 a top view of the relief grid of a security element according to a further exemplary embodiment.

An embodiment of the invention will now be explained using the example of security elements for banknotes. For this, fig. 1 shows a schematic diagram of a banknote 10 that is provided with an inventive optically variable security element 11. The security element 11 comprises, applied to the banknote substrate, a foil strip 12 that is provided in a sub-region 13 with a relief grid having a plurality of directionally reflective relief elements.

The sub-region 13 is additionally overprinted with a print line grid 14 that, on both sides of the foil strip 12, continues beyond the sub-region 13 onto the banknote paper. The designs and the line screens of the relief grid and the print line grid 14 are coordinated with each other in the manner described in greater detail below in such a way that a (for example colored) movement effect is created in the overlap area due to a moiré effect when the banknote 10 is tilted. For example, in the overlap region 13, multiple colored bars 15, 16 can be visible that appear to run downward or upward when the banknote 10 is tilted forward and backward.

The structure of a security element according to an embodiment of the present invention and the coming about of the conspicuous colored movement effect will now be explained in greater detail with reference to figures 2 and 3.

Fig. 2 shows an inventive security element 20 in cross section. The security element 20 is arranged on a banknote substrate 10 by means of an adhesive layer 22 and includes an embossing lacquer layer 24 in which is embossed a relief grid 30 that, prior to the application of the adhesive layer 22, was provided with a metalization 32, for example composed of aluminum or silver.

The relief grid 30 itself consists of a plurality of elongated grid elements 34 that connect with each other and whose longitudinal axis extends, in the diagram in fig. 2, into the plane of projection. Each grid element 34 consists of multiple parallel, line-type micromirrors 36 whose mirror slope in the figure changes almost continuously from a first, negative slope to a second, positive slope from the left edge of the grid elements 34 to the right edge. For example, the slope of a micromirror 36 can, in each case, be proportional to the signed spacing x between the micromirror 36 and the centerline 34-M of a grid element 34, such that the micromirrors 36 of a grid element 34 reproduce the reflection behavior of a parabolic concave mirror.

In the exemplary embodiment, the dimension of the grid elements 34 in the transverse direction, which simultaneously constitutes the line screen p of the relief grid 30, is p = 200 µm, with the width of the individual micromirrors 36 being around 22 µm. The dimension of the grid elements 34 and the micromirrors 36 in the longitudinal direction, that is, into the paper plane in fig. 2, is multiple millimeters or even centimeters, so is significantly larger than the line screen p. The width of the grid elements 34 and especially of the micromirrors 36, in contrast, is below the resolution limit of the human eye, such that the grid elements 34 and particularly the micromirrors 36 themselves cannot (or can only to a limited extent) be resolved with the naked eye.

Nevertheless, when the metalized relief grid 30 is viewed, a fine line grid is created for a viewer, as explained in greater detail with reference to fig. 3, although fig. 3(a) shows only the relief grid of the security element 20 and fig. 3(b) the visual appearance of the relief grid in (a). If, for example, light 40 is perpendicularly incident from above on the relief grid 30, as shown in fig. 3(a), then, for a viewer 42, the reflection condition "angle of incidence is equal to angle of reflection" is met only for a micromirror 36-B of a grid element 34.

In the top view 44 shown in fig. 3(b), said line-shaped micromirror 36-B thus appears as a light, fine line 46, while the regions 48 occupied by the other micromirrors reflect the incident light 40 in other spatial directions and thus appear dark for the viewer 42. Since the grid elements 34 and thus the micromirrors 36-B of the same orientation repeat at the spacing of the line screen p, the fine line grid 46 created likewise has a line screen p.

If the relief grid 30 in fig. 3 is tilted from left to right (that is, about an axis that extends parallel to the longitudinal direction of the micromirrors and thus into the paper plane in fig. 3(a)), then the position of the micromirror 36 for which the reflection condition is met migrates to the right such that also the lines 46 of the fine line grid in the top view 44 migrate to the right for the viewer 42. When tilted to the left, the reverse movement effect results accordingly.

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Coming back to the diagram in fig. 2, the security element 20 includes, in addition to said relief grid 30, a print layer in the form of a grid 50 of parallel spaced-apart print lines 52 that have a line screen q and that are imprinted on the embossing lacquer layer 24 surface opposite the relief grid 30 with a translucent printing ink. Here, the print lines 52 are aligned substantially parallel to the line-shaped micromirrors 36, and the two grids are coordinated with each other in such a way that the second line screen q differs only slightly from the first line screen p. In the exemplary embodiment, the second line screen q is 10% smaller than the first line screen p, so q = 180 µm.

Due to the slightly different line screens of the parallel grids of the print lines 52 and the micromirrors 36, their interplay results in a moiré effect in which a significantly coarser moiré line pattern 15, 16 (fig. 1) becomes visible for the viewer. In the case of the presently chosen difference of 10% between the two line screens, a moiré magnification factor of about 10 results, that is, the moiré line pattern 15, 16 has about 10 times the line screen, so in the present case around 1.8 mm.

Since the light lines of the fine line grid 46 run downward or upward when the banknote 10 is tilted, also the moiré line pattern 15, 16 moves accordingly. If the fine lines 46 move by a full period length, so here by p = 200 µm, then the bars 15 of the moiré line pattern likewise move by a period length, so by 1.8 mm. The microscopic movement effect of the line grid 46 that is hardly visible with the naked eye is thus magnified by the moiré effect to a movement that is easily perceptible for the viewer.

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To achieve a small thickness of the security element 20, the grid 50 of the print lines 52 is arranged at a small vertical spacing h above the relief grid 30. In the exemplary embodiment, the vertical spacing h is, for example, only about 10 µm, that is, only a twentieth of the line screen p.

Due to the use of a translucent, for example red, ink for the print line grid 52, it is additionally achieved that the moiré line pattern 15, 16 consists alternatingly of red and white (light) lines.

Overall, in the manner described, an optically variable security element is created having a one-dimensional relief grid composed of a plurality of grid elements that are each formed from multiple line-type micromirrors that are directionally reflective in different directions. The relief grid is combined with a print line grid arranged above the relief grid and, when tilted, displays an especially colored movement effect that is based on a moiré effect. Due to its small thickness, the described security element is particularly well suited for application to banknotes and other value documents.

The described relief grid 30 composed of micromirrors 36 can particularly advantageously be provided in the form of a foil element in which the micromirrors 36 are cast in an embossing lacquer 24, for example a radiation-curing or thermoplastic lacquer, applied on a carrier foil and are provided with a reflection-increasing coating, for example an aluminum metalization 32. Through the use of a foil having embossed micromirrors, a particularly high brilliance of the reflective surfaces and thus of the optically variable, colored movement effect is achieved.

The foil element can be applied to a banknote substrate and the carrier foil can be removed again after application to reduce the thickness such that substantially the embossing lacquer layer 24, the metalization 32 and the adhesive layer 22 are then present on the banknote 10, as shown in fig. 2. Here, in practice, further, albeit for an embodiment of the present invention non-essential, layers can be provided, such as a protective lacquer layer, ink-receiving layer or primer layer.

Over said layer sequence is then printed in the above-described manner the grid 50 of the print lines 52 to obtain the complete security element 20.

The grid of the print lines 50, 14 can continue beyond the edge of the relief grid 30 or of the foil strip 12, as shown in fig. 1. As a result, for one thing, the movement effect is particularly well integrated visually into the banknote design, and for another, the counterfeit security is increased, since a foil strip 12 detached from a banknote would have to be affixed to a counterfeited note in perfect register in order to preserve the registration of the foil strip 12 and the print line grid 14. Visually, in such a design, a colored movement effect is created in the overlap region 13, while outside the overlap region 13 the print line grid 14 appears substantially as a homogeneous halftone surface due to the small line spacing of the print lines ($q = 180\ \mu m$).

In the exemplary embodiment in fig. 2, all grid elements 34 are developed to be homogeneous, with, for each grid element 34, the slopes of the micromirrors 36 being chosen in such a way that the grid element 34 reproduces the reflection behavior of a parabolic concave mirror. It is also possible to have two or more different grid elements present in a relief grid 30. For example, the exemplary embodiment in fig. 4 shows a security element 60 that generally follows the structure described for fig. 2, but in which not only first grid elements 34 are provided that reproduce the reflection behavior of a parabolic concave mirror, but also second grid elements 62 that reproduce the reflection behavior of a parabolic convex mirror, as shown at the left edge of the image in fig. 4.

Compared with the grid elements 34, the slope of the micromirrors 36 is inverted in the second grid elements 62, that is, it goes from a first, positive slope to a second, negative slope from the left edge to the right edge. At the locations at which second grid elements 62 are provided instead of first grid elements 34, in the light line grid, for one thing, the position of the fine lines 46 produced changes, and for another, the lines produced by the convex-mirror-type grid elements 62 display an inverted movement behavior compared with the lines produced by the concave-mirror-type grid elements 34, since the sequence of the mirror slopes is precisely inverted. For example, the lines produced by convex-mirror-type grid elements 62 can run upward when the security element is tilted in one direction, while at the same time the lines produced by the concave-mirror-type grid elements 34 run downward. The movements can also run in a curve and intertwined, for instance within bands that are present in the form of a cord or a double helix.

It is also possible to provide more than one line grid arranged above the relief grid. For this, fig. 5 shows a security element 54 that generally follows the structure described for fig. 2, but in which two print line grids having parallel print lines 52, 56 are provided. Here, the print lines 56 are printed, for example with translucent green ink, in perfect register between the translucent red print lines 52. In the colored movement effect of the security element 54, a pattern composed of migrating alternating red and green bars then appears. Such a register-accurate print is easily possible in banknote printing particularly with small line screens q of about 100 µm, but very difficult for a potential counterfeiter to imitate.

In addition to the enhancement of a single movement effect by an additional color, an additional line grid can also produce a second, different movement effect. For instance, a first, for example red, print line grid can have a line screen q_1 that is slightly larger than the first line screen p, while a second, for example green, print line grid has a line screen q_2 that is slightly smaller than the first line screen p. When the security element is tilted, the red and green bars created by the moiré effect then move in opposite directions. In a two-sided security element, a further movement effect can also be produced on the opposite side of the relief grid and be visible from said side.

In other designs, given a fixed second line screen q, the first line screen p can vary locally. Interesting effects also result when the first line screen p and the second line screen q are fixed, but the curvature or the slope of the relief elements that form the grid elements is varied locally. For example, in the design in fig. 2, the slope of the micromirrors 36 in the middle grid element 34 could be twice as large as in the adjacent grid elements, and in this way, a modulation of the movement effect be produced. Said variation can then be continued periodically.

In the embodiments described so far, the grid elements each consisted of line-type micromirrors. However, it is also possible for the grid elements to be formed by appropriate Fresnel mirror structures, that is, by Fresnel lenses or Fresnel lens sections that are provided with a reflection-increasing coating. The Fresnel mirror structures here can correspond to both a concave and a convex curvature, or constitute a hybrid form composed of concave and convex sub-regions.

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For illustration, fig. 6(a) shows a top view of the relief grid 70 of an inventive security element that consists of a plurality of elongated grid elements 72 that connect with each other and that, in the diagram in fig. 6(a), extend from left to right and connect with each other from top to bottom. Each grid element 72 forms a cylindrical Fresnel mirror structure that corresponds to a concave curvature of a cylindrical diverging Fresnel lens and is provided, for example, with a reflective aluminum metalization. In this embodiment, the individual relief elements 74 are formed, not by line-shaped micromirrors 36 as in fig. 2, but by the coated line-shaped zones of the diverging Fresnel lens and thus generally have curved reflection surfaces.

Fig. 6(b) shows a top view of the complete security element 80, in which the relief grid 70 in fig. 6(a) is combined with two print line grids having print lines 82, 84 of different colors. Here, too, a moiré effect results due to the interplay of the relief grid 70 and the grid of the print lines 82, 84, due to which the viewer sees a colored movement effect with two different-colored bars that move up and down when the security element 80 is tilted in front of a light background.

In the modification in fig. 7, the relief grid is developed to be not one-dimensional, but two-dimensional. Fig. 7(a) shows a top view only of the relief grid 90 of the security element 100, and fig. 7(b) a top view of the complete security element 100. The two-dimensional relief grid 90 consists of a plurality of grid elements 92 that connect with each other in both spatial directions, the line screens p_1, p_2 in the exemplary embodiment shown being identical in the two spatial directions and both being, for example, 200 µm. Each grid element 92 forms a spherical Fresnel mirror structure that corresponds to a concave curvature of a spherical diverging Fresnel lens and is provided, for example, with a reflective aluminum metalization. In said embodiment, the individual relief elements 94 are formed by the coated ring-shaped zones of the diverging Fresnel lens and comprise curved reflection surfaces.

In the complete security element 100, the relief grid 90 in fig. 7(a) is combined with two print line grids having print lines 82, 84 of different colors. Also in the case of a two-dimensional relief grid, a moiré effect results due to the interplay of the relief grid 90 and the grid of the print lines 82, 84, due to which the viewer sees a colored movement effect with two different-colored bars that move up and down when the security element 100 is tilted in front of a light background.

In the exemplary embodiment in fig. 7, due to the orientation of the print lines 82, 84 in the x-direction, of the two line screens p_1, p_2, only the line screen p_2 comes to bear in the moiré effect. In other designs, however, the print lines can also be oriented in the y-direction, or a first print line grid includes print lines in the x-direction and a second print line grid includes print lines in the y-direction, such that both line screens of the relief grid come to bear.

In the exemplary embodiment in fig. 8, the relief grid is two-dimensional with two different line screens p_1 and p_2 in the x- and y-direction. Fig. 8(a) shows a top view only of the relief grid 110 of the security element 120, and fig. 8(b) shows a top view of the complete security element 120. The two-dimensional relief grid 110 consists of a plurality of grid elements 112 that connect with each other in both spatial directions, the line screens p_1, p_2 being different in the two spatial directions and being, for example $p_1 = 300\ \mu m$

and p_2 = 150 µm. Each grid element 112 forms an elliptical Fresnel mirror structure that corresponds to a convex curvature of an elliptical converging Fresnel lens and is provided, for example, with a reflective aluminum metalization. In said embodiment, the individual relief elements 114 are formed by the coated ring-shaped zones of the diverging Fresnel lens and comprise curved reflection surfaces.

In the complete security element 120, the relief grid 110 in fig. 8(a) is combined with two print line grids having print lines 122, 124 of different colors and orientations. The print lines 122 of the first print line grid lie parallel to the y-direction and have a line screen q_1 that differs only slightly from the line screen p_1. The print lines 124 of the second print line grid lie parallel to the x-direction and have a line screen q_2 that differs only slightly from the line screen p_2. Depending on the specific choice of the line screens q_1, q_2 in relation to the line screens p_1, p_2, different movement effects can be produced in which, for example, the moiré line grid moves at different speeds when the security element is tilted from right to left and when tilted from top to bottom.

Fig. 9 shows another exemplary embodiment of the present invention, in which the relief grid 110 of the security element 140 is developed as described in connection with fig. 8. The relief grid 110 is combined with a print dot grid 142 whose grid points 144 in the exemplary embodiment are each developed in the form of the euro symbol (€). The print dot grid 142, like the relief grid 110, is two-dimensional and has two different line screens q_1 and q_2 in the x- and y-directions. Here, the line screen q_1 differs only slightly from the line screen p_1 and the line screen q_2 differs only slightly from the line screen p_2. Depending on the specific choice of the line screens q_1, q_2 in relation to the line screens p_1, p_2, different movement effects can be produced in which, for example, the moiré-magnified € symbols move at different speeds when the security element is tilted from right to left and when tilted from top to bottom.

The exemplary embodiment in fig. 10 is a modification of the exemplary embodiments in fig. 7 and 8. First, the relief grid 110 of the security element 150 is again developed as already described in connection with fig. 8. Similar to the exemplary embodiment in fig. 7, the relief grid 110 is combined with two print line grids having print lines 152, 154 of different colors. The grids of the print lines 152, 152 each have, in the y-direction, a line screen q_2 that differs only slightly from the line screen p_2 of the relief grid.

In contrast to the design in fig. 7, however, the print lines 152, 154 comprise additional gap regions 156 and 158 that are developed in the form of a € symbol. In the x-direction, the gap regions 156 and 158 are arranged having a line screen q_1 that, at most, differs slightly from the line screen p_1 of the relief grid. Due to the interplay of the two-dimensional relief grid 110, the grid of the print lines 152, 154 and the grid of the gaps 156, 158 in the print lines, there results for the viewer a colored movement effect with two different-colored bars that display moiré-magnified gaps in the form of the € symbol. The bars move together with the gaps when the security element 150 is tilted up and down in front of a light background. Furthermore, through a suitable coordination of the line screens p_1 and q_1, it can be achieved that the moiré-magnified gaps appear to shift within the bars when the security element is tilted from right to left.

In the designs in figures 7 to 10, the grid elements need not necessarily connect with each other and completely fill the plane of the security element, but can also be arranged spaced apart from one another and even be developed in motif form. For illustration, figure 12(a) shows a top view of a security element 160 having a two-dimensional relief grid 162 composed of a plurality of grid elements 164, each having a star-shaped contour, arranged spaced apart. With the exception of the motif-shaped contour, the grid elements 164 are developed like the grid elements 92 in fig. 7, that is, they each form a spherical Fresnel mirror structure that corresponds to the concave curvature of a spherical diverging Fresnel lens and is provided, for example, with a reflective aluminum metalization. The relief grid 162 is combined with two print line grids having print lines 82, 84 of different colors, for example red print lines 82 and yellow print lines 84.

When the security element 160 is viewed, a magnified piece of moiré macro-information having the shape of the relief elements 164 is created by the moiré effect. In the exemplary embodiment, there is created, for instance, a plurality of moiré-magnified stars 166, 168, as illustrated in fig. 12(b) and (c), that show the appearance of the security element 160 in perpendicular or oblique top view. A tilting of the security element 160 leads, on one hand, to a migration of the magnified stars 166, 168. In addition, due to the different colors of the print lines 82, 84, a color change occurs such that, for example, a red star 166 when viewed perpendicularly (fig. 12(b)) can appear as a yellow star 168 when viewed obliquely (fig. 12(c)) and vice versa. It is understood that motif-shaped, spaced-apart relief elements can be used not only in the embodiment in fig. 7, but in all described embodiments in place of relief elements that connect with each other.

A location-dependent modulation of the relief grid 170 through location-dependent focal-point shift is illustrated in fig. 13, which, similar to fig. 7(a), shows only the relief grid 170 of a security element according to an embodiment of the present invention. It is understood that the relief grid 170 is combined with at least one dot and/or line grid in the manner described to form a complete security element.

The two-dimensional relief grid 170 consists of a plurality of grid elements that connect with each other in both spatial directions and that have spherical Fresnel mirror structures of the kind already generally described in greater detail for fig. 7(a). For illustration, in fig. 13, the grid elements 172 of the upper row shown are developed without focal-point shift, the center of the spherical Fresnel mirror structure 176 in these elements thus also lies in the center of each grid element 172. In the lower row, grid elements 174 having different focal-point shifts are shown, that is, in which the center of the spherical Fresnel mirror structure 176 does not coincide with the center of the grid elements 174, but comprises a certain shift (Δx, Δy). In practice, said shift is advantageously given by a formulaic relationship, for example to produce the effect of a pumping circle.

Further, it is also possible to provide a subset of the grid elements with a focal-point shift by a certain shift value in order to set the piece of information formed by the shape of the subset apart from and in contrast to its surroundings. Said variant is especially expedient in interplay with dot and/or line grids of different colors, the shift value of the grid elements advantageously being coordinated with the spacing of the dot and/or line grid in such a way that the piece of information formed by the subset appears having maximum color contrast. When the security element is tilted, at certain tilt angles, precisely the reverse color impression can then result.

Fig. 11 shows a security element 130 according to a further exemplary embodiment of the present invention, in cross section. The security element 130 comprises, arranged on the banknote substrate 10, a contiguous print layer 138, for example a red ink layer, a transparent hot-melt adhesive layer 22 and an embossing lacquer layer 24 in which is embossed a relief grid 30 that is provided with a metalization applied in the form of a line grid 132.

The relief grid 30 consists of a plurality of elongated grid elements 34 that are connected with each other and that can consist, for example, of multiple line-type micromirrors as in the exemplary embodiment in fig. 2, or of a cylindrical Fresnel mirror structure as in the exemplary embodiment in fig. 6. The relief grid 30 has a first line screen p below 500 µm.

The line grid 132 present directly on the relief grid 30 consists alternatingly of metallic lines 134 and demetalized lines 136, and has a second line screen q that differs only slightly from the first line screen p, for example by 5%. In this exemplary embodiment, the line grid 132 of the metallic lines 134 and demetalized lines 136 is present directly on the relief grid 30 such that the vertical spacing between the relief grid 30 and the line grid 132 is equal to zero.

The line grid 132 can be produced, for example, through contiguous metalization of the embossed embossing lacquer layer 24 and subsequent demetalization in some regions through a suitable demetalization process, for example through the washing process known from document WO 99/13157 A1. Alternatively, also, for example, an etching mask can be printed and the demetalization carried out in an etching process. Also a demetalization by means of laser is conceivable. As in the printed line grids, the relief grid 30 can also be combined with multiple metallic line grids that can also have different line screens and/or different line orientations.

When the security element 130 is viewed, in the demetalized line regions 136, the view of the red print layer 138 is revealed such that said layer appears as red lines. In interaction with the fine line grid produced by the metalized line regions 134, the grid of red lines produces a moiré effect and a magnified moiré line pattern, as already generally described above.

Since the print layer 138 appears precisely in the demetalized line regions 136, perfect register results between the red lines visible there and the metallic lines 134.

The print layer 138 can also be multicolored and thus produce different-colored movement effects in different sub-regions of the security element 130.

Alternatively or in addition to the print layer 138, the embossing lacquer layer 24 itself can also be developed to be colored transparent, or there can be provided, arranged on the embossing lacquer layer 24, a contiguous print layer, for example a transparent or translucent ink layer to produce a colored line grid. In this way, the colored embossing lacquer layer 24 or the colored print layer arranged on the embossing lacquer layer 24 appears particularly in the demetalized line regions 136 as colored lines.

Any reference to publications cited in this specification is not an admission that the disclosures constitute common general knowledge.

List of reference signs

10	Banknote
11	Security element
12	Foil strip
13	Sub-region
14	Print line grid
15, 16	Colored bars
20	Security element
22	Adhesive layer
24	Embossing lacquer layer
30	Relief grid
32	Metalization
34	Grid elements
34-M	Centerline of a grid element
36, 36-B	Micromirrors
40	Light
42	Viewer
44	Top view
46	Fine lines
48	Other regions
50	Grid
52	Print lines
54	Security element
56	Print lines
60	Security element
62	Second grid elements

70	Relief grid
72	Grid elements
74	Relief elements
80	Security element
82, 84	Print lines
90	Relief grid
92	Grid elements
94	Relief elements
100	Security element
110	Relief grid
112	Grid elements
114	Relief elements
120	Security element
122, 124	Print lines
130	Security element
132	Line grid
134	Metallic lines
136	Demetalized lines
138	Printing layer
140	Security element
142	Print dot grid
144	Grid points
150	Security element
152, 154	Print lines
156, 158	Gap regions
160	Security element
162	Relief grid
164	Grid elements
166, 168	Magnified stars

170	Relief grid
172, 174	Grid elements
176	Spherical Fresnel mirror structure

Claims

1. An optically variable security element for securing valuable articles, having

– a one- or two-dimensional relief grid that is composed of a plurality of grid elements and that has a first line screen p below 500 µm in at least one spatial direction and in which the grid elements are each formed from at least two relief elements that are directionally reflective in different directions, and

– having at least one dot and/or line grid that is arranged vertically above or below the relief grid and has a second line screen q in said spatial direction, the second line screen q differing only slightly from the first line screen p, namely by less than one-fifth, and/or the first line screen p and/or the second line screen q being location-dependently modulated such that a movement effect is created by the interplay of the relief grid and the dot and/or line grid when the security element is tilted,

– and the vertical spacing between the relief grid and the dot and/or line grid being less than half the line screen p.

2. The security element according to claim 1, **characterized in that** at least one, preferably all, of the dot and/or line grids are designed as line grids.

3. The security element according to claim 2, **characterized in that** at least one line grid is a print line grid that preferably is formed at least in a sub-region from a plurality of substantially parallel print lines having a spacing q.

4. The security element according to claim 3, **characterized in that** the print line grid is separated from the relief grid by a spacing layer, the spacing layer advantageously including an embossing lacquer layer in which the relief elements of the relief grid are embossed.

5. The security element according to at least one of claims 1 to 4, **characterized in that** the relief elements of the relief grid are provided with a reflection-increasing coating, especially a metalization.

6. The security element according to at least one of claims 1 to 5, **characterized in that** at least one dot and/or line grid is formed by a reflection-increasing coating, present in dot and/or line grid form, of the relief elements of the relief grid, preferably **characterized in that** the relief grid is combined with a background layer, especially a contiguous ink layer, that lies below the reflection-increasing coating.

7. The security element according to claim 6, **characterized in that** the relief grid is combined with a colored transparent or translucent layer that lies above the reflection-increasing coating.

8. The security element according to at least one of claims 1 to 7, **characterized in that** the vertical spacing between the relief grid and the line grid is less than one-fifth, preferably less than one-tenth of the line screen p, especially less than 15 µm.

9. The security element according to at least one of claims 1 to 8, **characterized in that** the relief grid is a one-dimensional grid that is composed of a plurality of elongated grid elements, that has said line screen p, and in which the grid elements are each formed from at least two line-type relief elements that are directionally reflective in different directions, preferably **characterized in that** the grid elements are each formed from a plurality of line-type micromirrors or from a cylindrical Fresnel mirror structure.

10. The security element according to at least one of claims 1 to 8, **characterized in that** the relief grid is a two-dimensional grid that is composed of a plurality of grid elements, that has said line screen p in a first spatial direction, and in which the grid elements are preferably each formed from at least two, preferably at least three, particularly preferably at least four relief elements that are directionally reflective in different directions, preferably **characterized in that** the grid elements are each formed from a circular or elliptical arrangement of a plurality of micromirrors or a spherical or elliptical Fresnel mirror structure.

11. The security element according to claim 10, **characterized in that** the grid elements are arranged having a motif-shaped contour and spaced apart from one another.

12. The security element according to at least one of claims 1 to 11, **characterized in that** the grid elements are each formed from a plurality of relief elements that are directionally reflective in different directions, especially in a one-dimensional grid are formed from at least 10 line-type relief elements that are directionally reflective in different directions, and in

a two-dimensional grid are formed from at least 10 x 10 relief elements that are directionally reflective in different directions.

13. The security element according to at least one of claims 1 to 12, **characterized in that** the reflective relief elements of each grid element are arranged and designed in such a way that the grid element produces the reflection behavior of a concave or convex curvature, preferably **characterized in that** the relief grid includes two or more different grid elements that preferably each produce different movement effects when the security element is tilted..

14. The security element according to at least one of claims 1 to 12, **characterized in that** the grid elements are all designed to be homogeneous.

15. The security element according to at least one of claims 1 to 14, **characterized in that** the dot and/or line grid comprises a plurality of parallel lines that run substantially perpendicular to the first spatial direction.

16. The security element according to at least one of claims 1 to 15, **characterized in that** two or more dot and/or line grids that are arranged vertically above or below the relief grid are provided, especially in that at least one dot and/or line grid is arranged above and at least one dot and/or line grid is arranged below the relief grid.

17. The security element according to at least one of claims 1 to 16, **characterized in that** the first line screen p is fixed and the second line screen

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q is location-dependently modulated, or in that the second line screen q is fixed and the first line screen p is location-dependently modulated.

18. The security element according to at least one of claims 1 to 17, **characterized in that** the first and/or second line screen is location-dependently modulated in that the positions of the grid elements of the relief grid or of the dot and/or line grid are given by a phase function $\phi(x,y)$ that depends on the position (x,y) of the grid element in the security element and whose function value indicates the deviation of the position of the grid element from the position of a grid point in a regular grid, normalized to the unit interval [0,1], and the phase function $\phi(x,y)$ varying location dependently in such a way that a movement effect, especially a pump or rotation effect, is created when the security element is tilted.

19. The security element according to at least one of claims 1 to 18, **characterized in that** the security element is a security thread, especially a window security thread or a pendulum security thread, a security band, or a security strip, preferably at least one line grid of the security element covering the relief grid in sub-regions and in sub-regions extending outside the relief grid to the data carrier provided with the security element.

20. A method for manufacturing an optically variable security element according to one of claims 1 to 19, in which

– a one- or two-dimensional relief grid composed of a plurality of grid elements and at least one dot and/or line grid are vertically stacked one on top of another,

- the relief grid being developed having a first line screen p below 500 µm in at least one spatial direction,

- the grid elements of the relief grid each being formed from at least two relief elements that are directionally reflective in different directions,

- the at least one dot and/or line grid being developed having a second line screen q in said spatial direction, the second line screen q differing only slightly from the first line screen p, namely by less than one-fifth, and/or the first line screen p and/or the second line screen q being location-dependently modulated such that a movement effect is created by the interplay of the relief grid and the line grid when the security element is tilted,

- and the vertical spacing between the relief grid and the dot and/or line grid being less than half the line screen p.

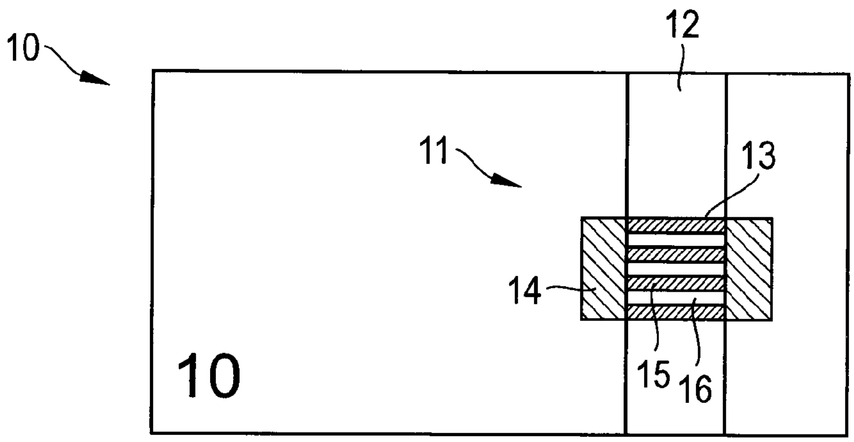

Fig. 1

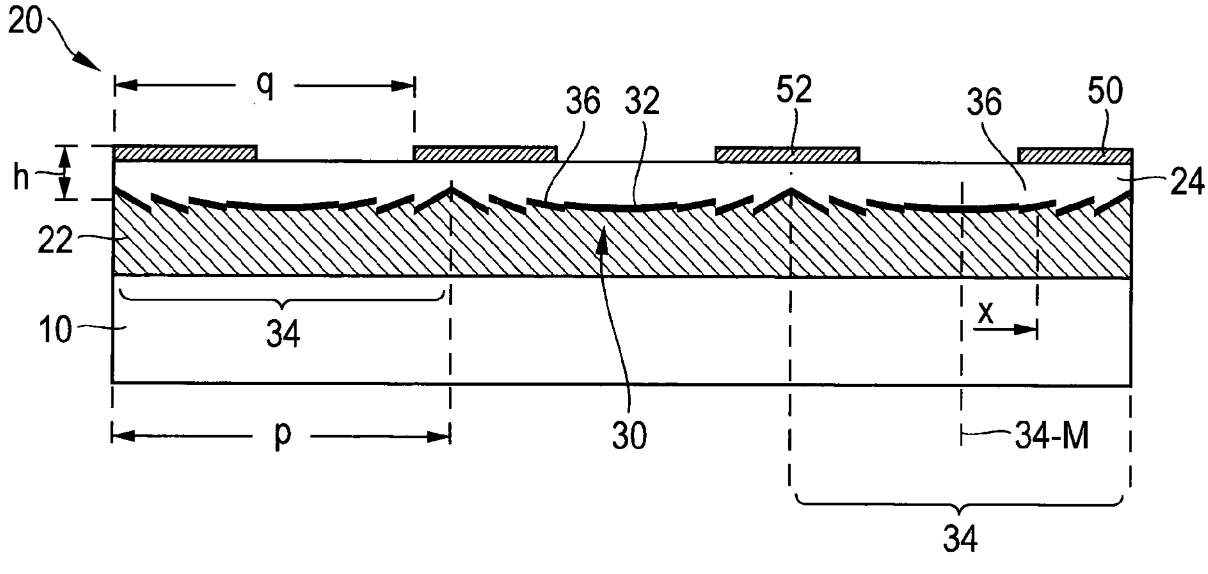

Fig. 2

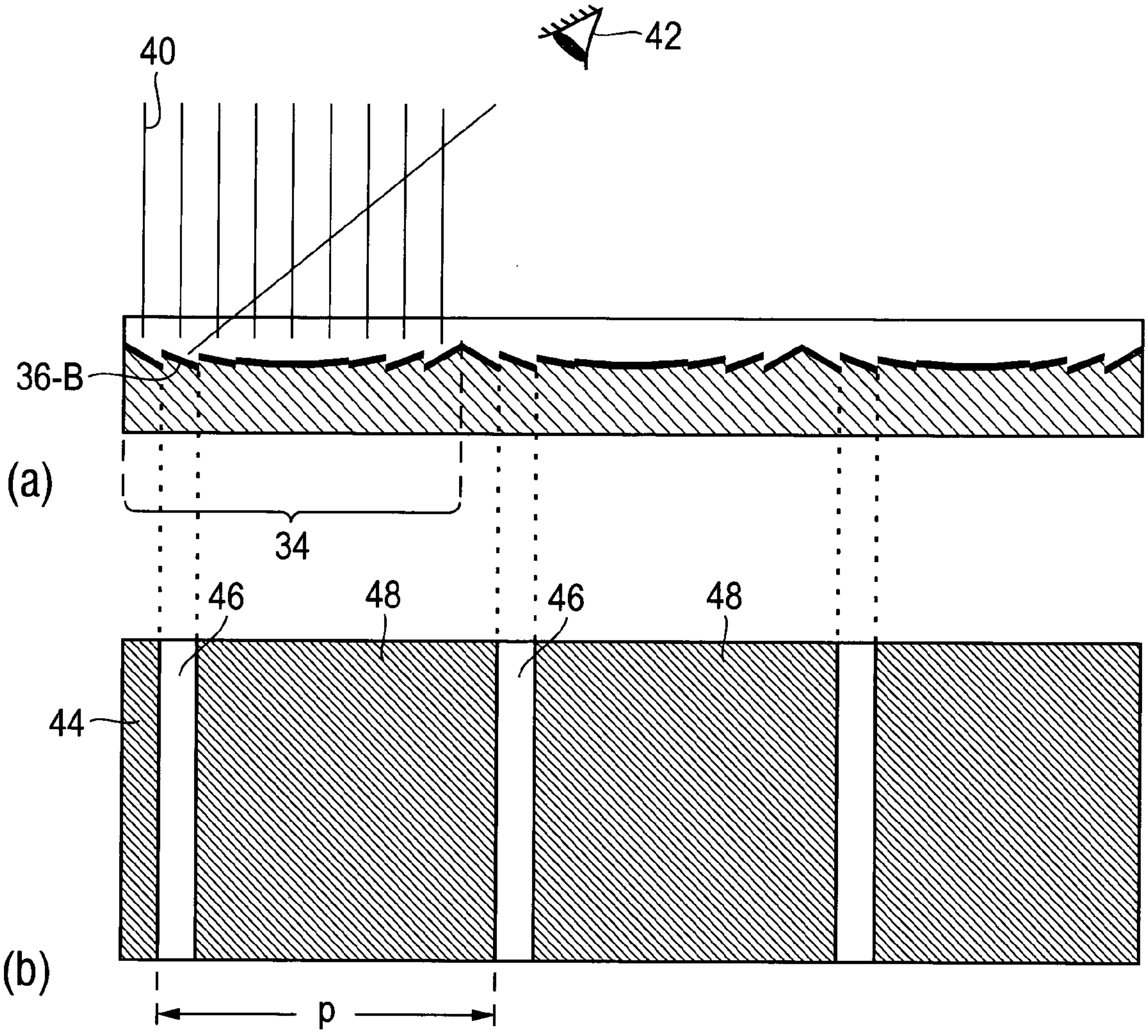

Fig. 3

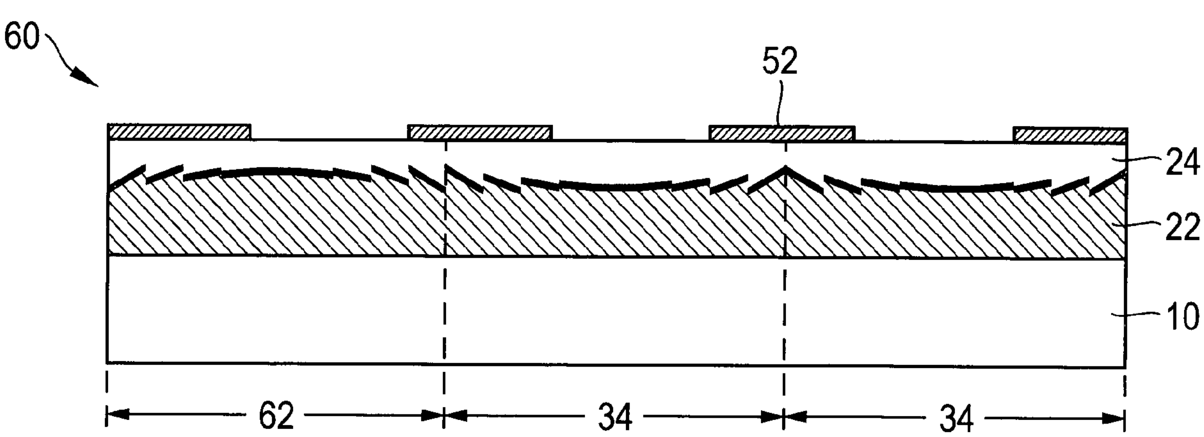

Fig. 4

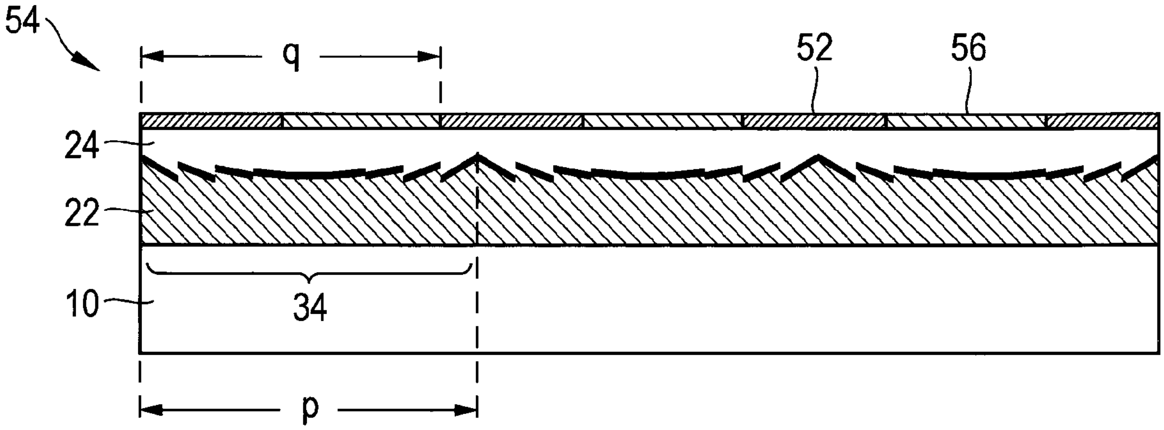

Fig. 5

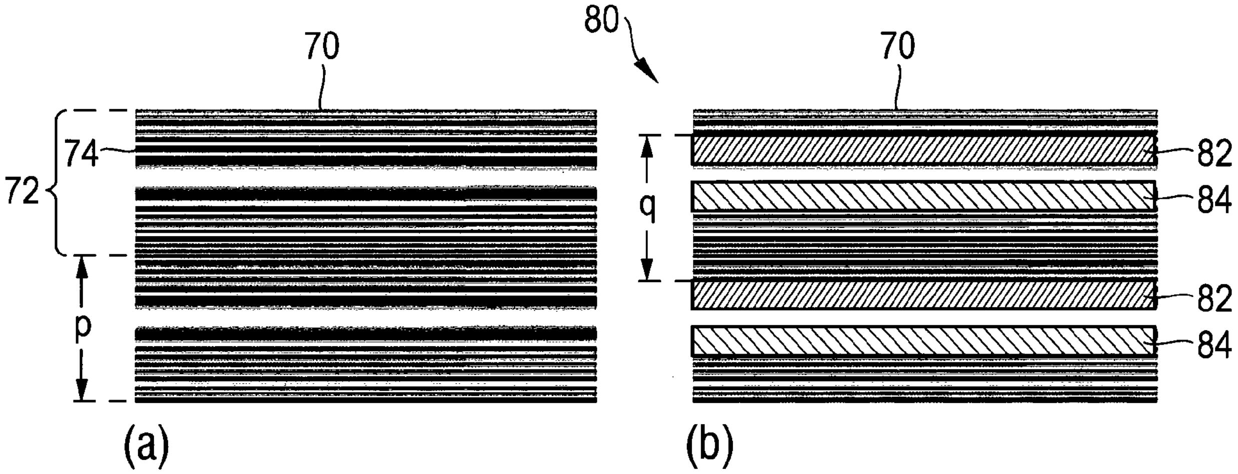

Fig. 6

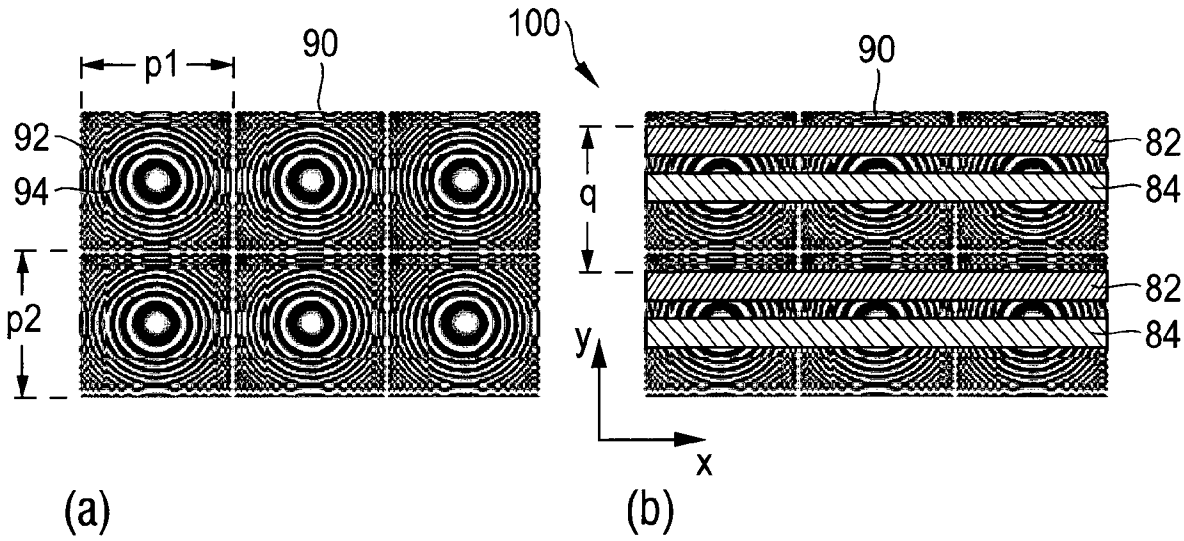

Fig. 7

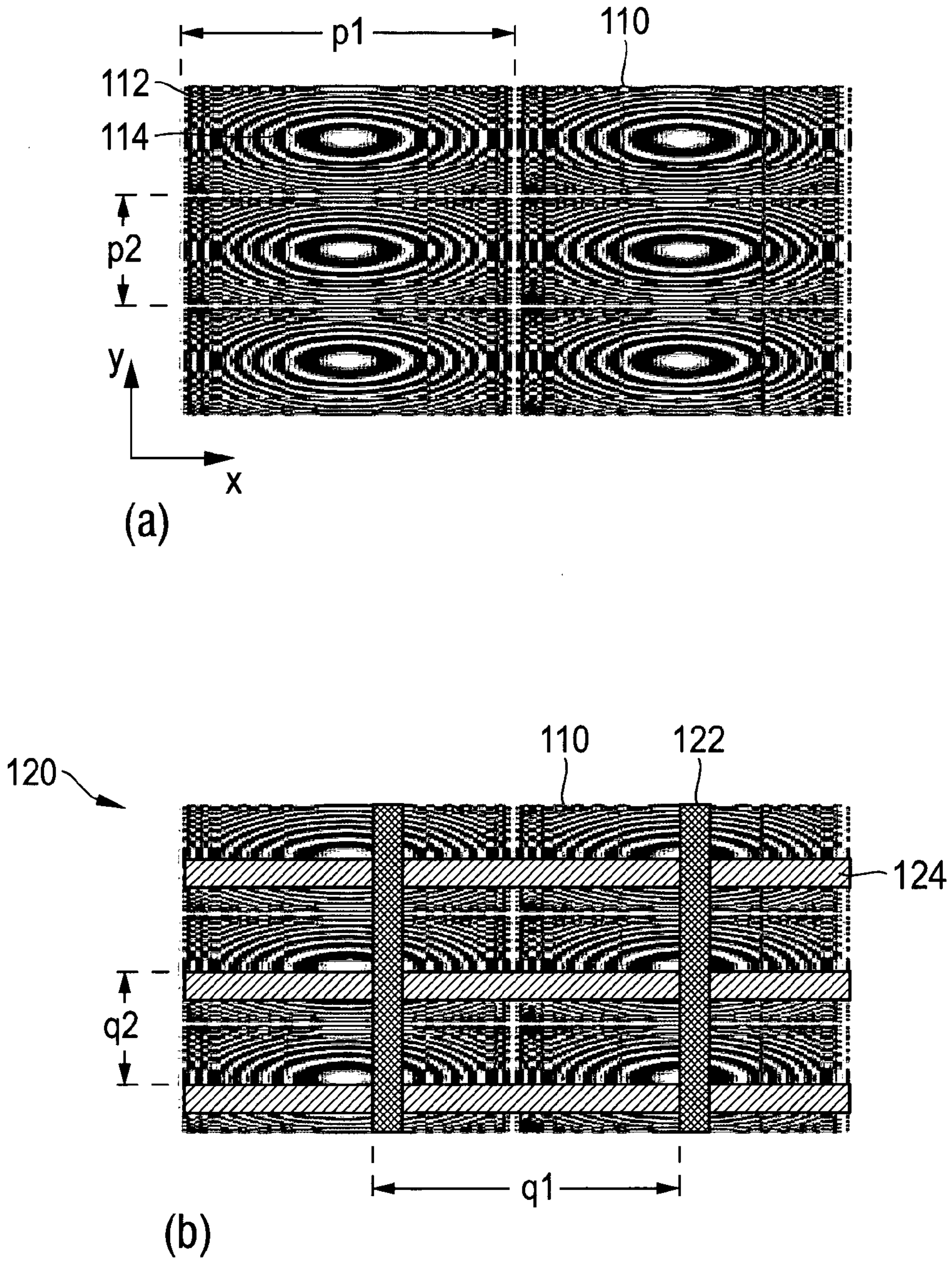

Fig. 8

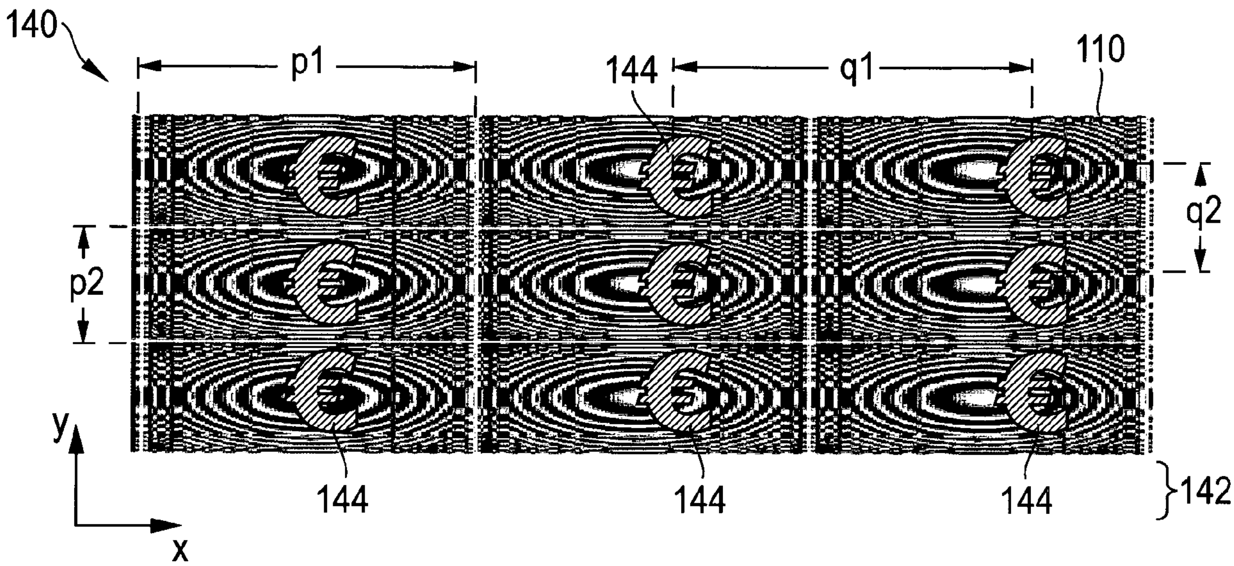

Fig. 9

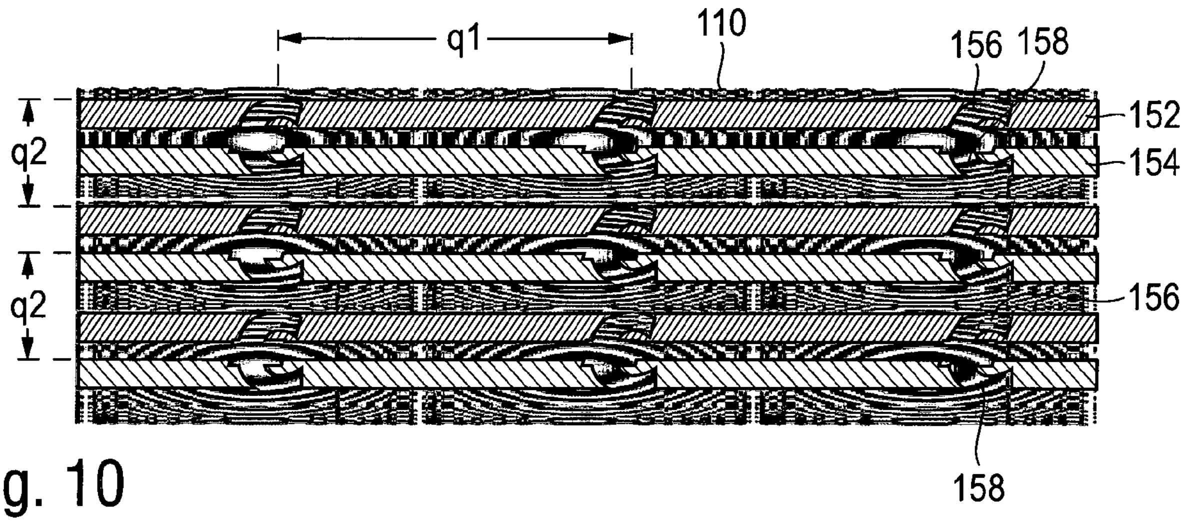

Fig. 10

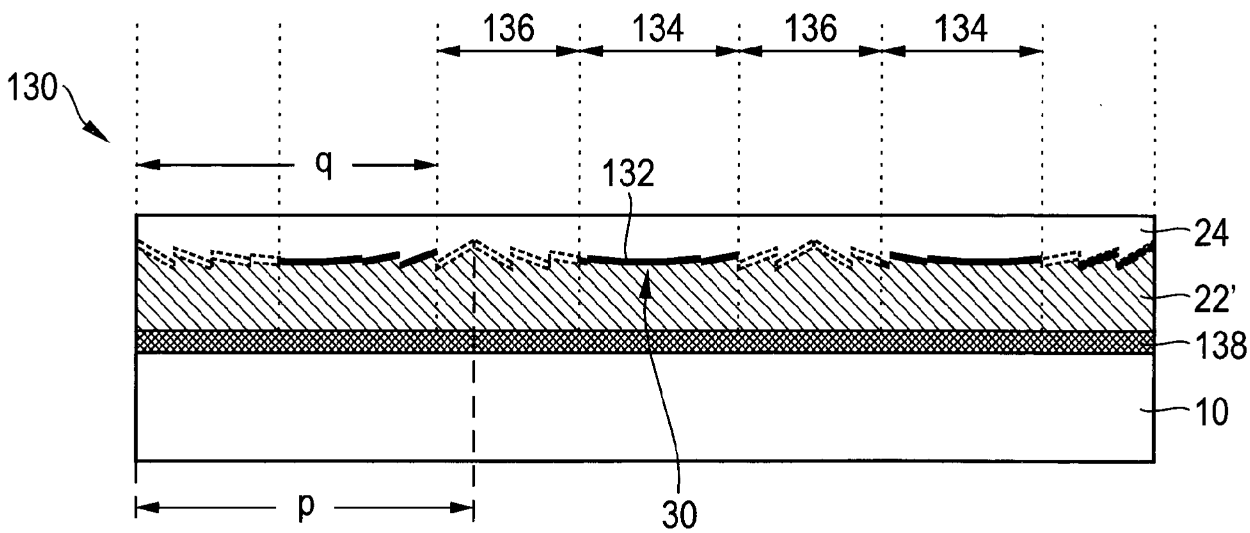

Fig. 11

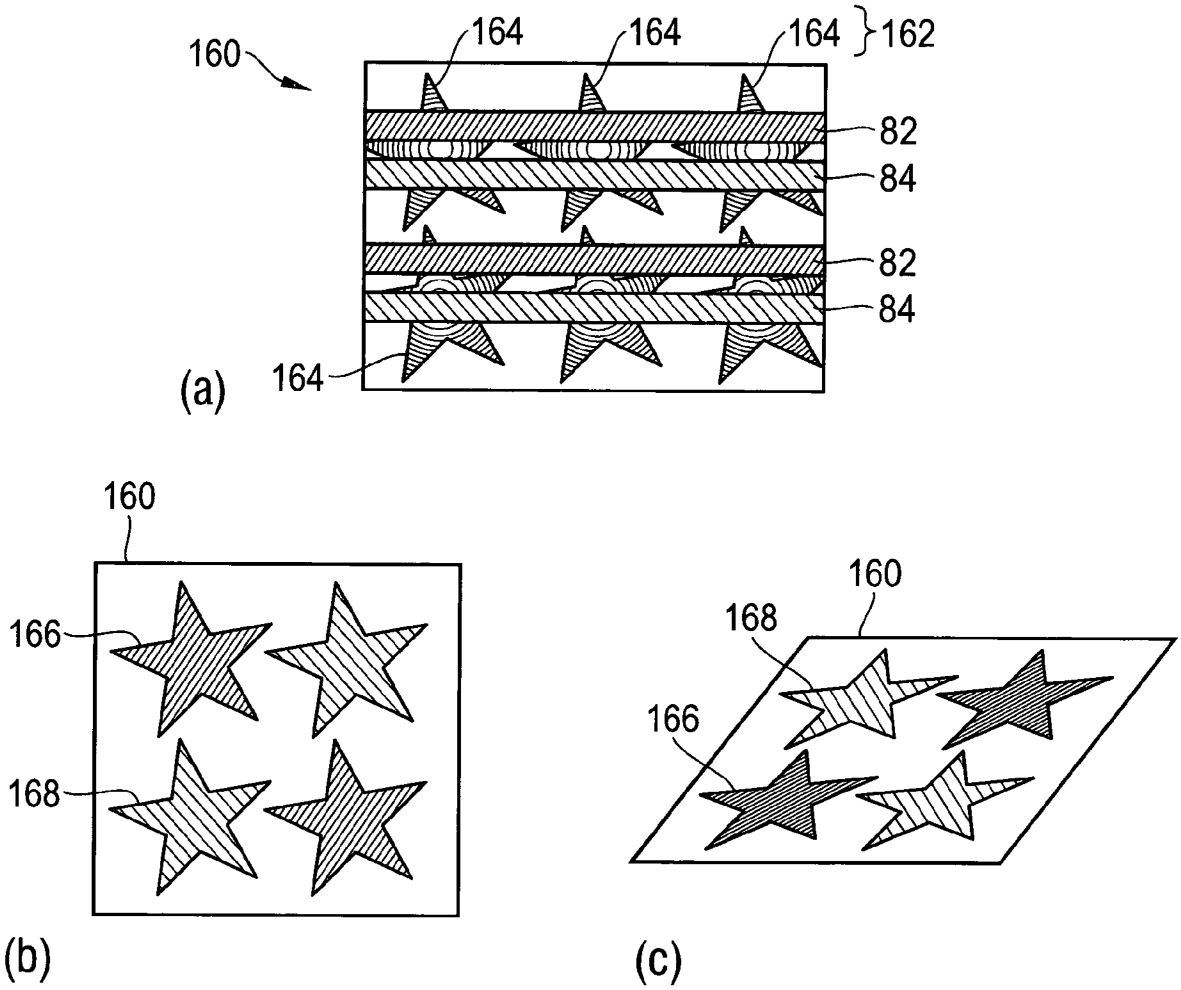
160
164
164
164
162
82
84
82
84
164
(a)
160
166
168
(b)
160
168
166
(c)

Fig. 12

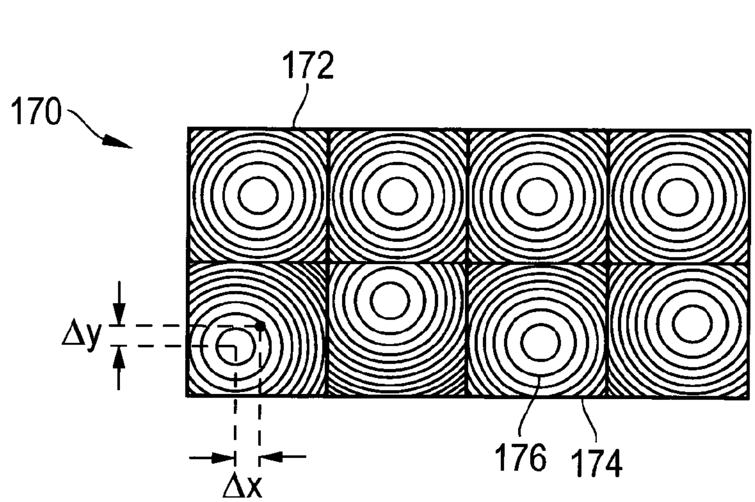
172
170
Δy
Δx
176
174

Fig. 13