Innovation, Sciences et Développement économique Canada
Office de la Propriété Intellectuelle du Canada

Innovation, Science and Economic Development Canada
Canadian Intellectual Property Office

CA 2879428 C 2021/05/04

(11)(21) **2 879 428**

(12) **BREVET CANADIEN**
CANADIAN PATENT

(13) **C**

(86) Date de dépôt PCT/PCT Filing Date: 2013/07/18
(87) Date publication PCT/PCT Publication Date: 2014/01/23
(45) Date de délivrance/Issue Date: 2021/05/04
(85) Entrée phase nationale/National Entry: 2015/01/19
(86) N° demande PCT/PCT Application No.: EP 2013/002132
(87) N° publication PCT/PCT Publication No.: 2014/012667
(30) Priorité/Priority: 2012/07/20 (DE10 2012 014 414.8)

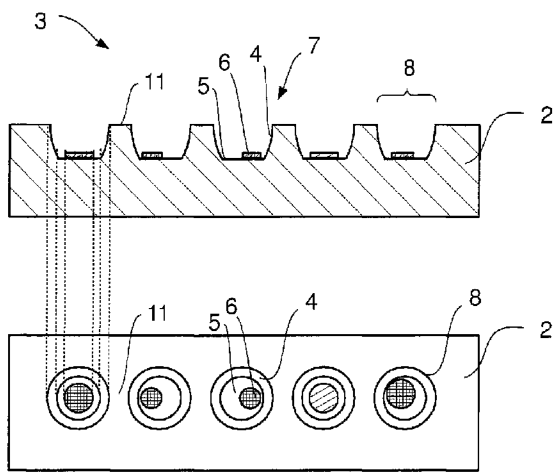
(51) Cl.Int./Int.Cl. *B42D 25/328* (2014.01), *B41M 3/14* (2006.01), *B42D 25/342* (2014.01), *B42D 25/373* (2014.01), *B42D 25/40* (2014.01), *G02B 5/18* (2006.01)

(72) Inventeur/Inventor:
LOCHBIHLER, HANS, DE

(73) Propriétaire/Owner:
GIESECKE+DEVRIENT CURRENCY TECHNOLOGY GMBH, DE

(74) Agent: RIDOUT & MAYBEE LLP

(54) Titre : ELEMENT DE SECURITE POUR PAPIERS DE SECURITE, DOCUMENTS FIDUCIAIRES OU SIMILAIRES
(54) Title: SECURITY ELEMENT FOR SECURITY PAPERS, VALUE DOCUMENTS OR THE LIKE



(57) Abrégé/Abstract:
The invention relates to a security element for an object to be protected such as a security paper, value document or the like, the security element having a substrate (2) with a plurality of microreflectors (4) arranged in a pattern and a plurality of microstructures which, together with the microreflectors (4), produce an image perceptible by a viewer. Each microstructure is formed as a reflective grating (6) and associated with one of the microreflectors (4), whereby grating reflectors (7), each consisting of one microreflector (4) and at least one grating (6) are formed. Each grating (6) is designed such that it diffracts visible radiation (9) incident from a half-space into a first diffraction order and towards the associated microreflector (4). The grating (6) and the microreflector (4) in each grating reflector (7) are matched to one another such that radiation which was diffracted by the grating (6) into the first grating order is reflected by the microreflector (4) as return radiation (10) into the half-space, and inside the pattern at least one of the flowing properties of the grating reflectors (7) varies to produce the image: diffraction property of the gratings (6), position of the gratings (6) relative to the respectively associated microreflector (4) and/or reflection property of the microreflectors (4).

Abstract

The invention relates to a security element for an object to be protected, such as e.g. a security paper, value document or the like, which has a substrate (2) with a plurality of microreflectors (4) disposed in a pattern and a plurality of microstructures which together with the microreflectors (4) produce an image perceptible to a viewer, wherein each microstructure is configured as a reflective grating (6) and associated with one of the microreflectors (4), thereby forming grating reflectors (7) consisting of a respectively microreflector (4) and at least one grating (6), each grating (6) is so configured that it diffracts visible radiation (9) incident from a half-space into a first diffraction order and toward the associated microreflector (4), in each grating reflector (7) the grating (6) and the microreflector (4) are matched to each other such that the microreflector (4) reflects radiation diffracted by the grating (6) into the first diffraction order back into the half-space as return radiation (10), and within the pattern at least one of the following properties of the grating reflectors (7) varies to produce the image: diffracting property of the gratings (6), position of the gratings (6) relative to the respectively associated microreflector (4), reflecting property of the microreflectors (4).

Security element for security papers, value documents or the like

[0001] This invention relates to a security element for an object to be protected, such as e.g. a security paper, value document or the like, which has a plurality of microreflectors disposed in a pattern and a plurality of microstructures which together with the microreflectors produce an image perceptible to a viewer.

[0002] The invention relates further to a security paper or value document.

[0003] The invention finally also relates to a method for manufacturing a security element for an object to be protected, such as e.g. a security paper, value document or the like, wherein there are formed on a substrate a plurality of microreflectors disposed in a pattern and a plurality of microstructures which together with the microreflectors produce an image perceptible to a viewer.

[0004] Objects to be protected are frequently equipped with a security element which allows the authenticity of the object to be checked and thus serves as protection from unauthorized reproduction. Such objects are for example security papers, identity documents or value documents (such as e.g. bank notes, chip cards, passports, identification cards, badge cards, shares, bonds, deeds, vouchers, checks, admission tickets, credit cards, health cards) as well as product authentication elements, such as e.g. labels, seals and packages. They may also be products themselves, such as for example capsules of a drug for which forgeries are to be feared.

[0005] For security elements the prior art describes in detail so-called moiré magnification arrangements, for example in WO 2005/106601 A2, EP 1979768 A1, EP 1182054 B1, WO 2011/029602 A2, WO 2002/101669 A2 and EP 1893074 A2. Such magnification arrangements combine focusing elements with microimages which are located in the image plane of the focusing elements. The microimages are aligned with the focusing elements such that a synthetic image results upon viewing of the security element due to the so-called moiré effect. Said synthetic image has properties (for example an orthoparallactic effect) that are not reproducible by simply copying the images.

[0006] The focusing elements can be configured as microlenses or microreflectors. The latter design corresponds to the generic type stated at the outset and is the subject matter of WO 2010/136339 A2 and WO 2011/012460 A2.

[0007] Known moiré magnification arrangements have in common that the microimages are a greatly reduced form of at least a partial detail of the synthetic image. They are formed by relief surfaces corresponding to the image content which are filled with color or which otherwise have light-absorbing properties. For the light absorption it is also known from the stated prints to employ regular or irregular subwavelength structures which act as light traps and are therefore also designated as moth-eye structures.

[0008] Known security elements require a distance between microimages and focusing elements that corresponds approximately to the focal length of the focusing elements. The prior art normally satisfies this requirement by microimages and microfocusing elements being disposed on opposing sides of a foil whose thickness corresponds approximately to the focal length of the focusing elements. This procedure requires the foil to be embossed on both sides in very exact mutual register. This is elaborate and therefore disadvantageous.

[0009] The invention is based on the object of remedying this disadvantage in a security element, security paper or value document and in a manufacturing method of the type stated at the outset, i.e. of doing without the strict registration demands required in the prior art.

[0010] This object is achieved according to the invention by a security element for an object to be protected, such as e.g. a security paper, value document or the like, which has a plurality of microreflectors disposed in a pattern and a plurality of microstructures which together with the microreflectors produce an image perceptible to a viewer, wherein each microstructure is configured as a reflective grating and associated with one of the microreflectors, thereby forming grating reflectors each consisting of one microreflector and at least one grating, each grating is so configured that it diffracts visible radiation incident from a half-space into a first diffraction order and toward the associated microreflector, in each grating reflector the grating and the microreflector are matched to each other such that the microreflector reflects radiation diffracted by the grating into the first diffraction order back into the half-space, and within the pattern at least one of the following properties of the grating reflectors varies to produce the image: diffracting property of the gratings, position of the gratings relative to the respectively associated microreflector, reflecting property of the microreflectors.

[0011] The object is further achieved with a security paper or value document having such a security element.

[0012] The object is finally likewise achieved with a method for manufacturing a security element for an object to be protected, such as e.g. security papers, value documents or the like, wherein there are formed on a substrate a plurality of microreflectors disposed in a pattern and a plurality of microstructures which together with the microreflectors produce an image perceptible to a viewer, wherein each microstructure is configured as a reflective grating and associated with one of the microreflectors, thereby forming grating reflectors each consisting of one microreflector and at least one grating, wherein each grating is so configured that it diffracts visible radiation incident from a half-space into a first diffraction order and toward the associated microreflector, in each grating reflector the grating and the microreflector are matched to each other such that the microreflector reflects radiation diffracted by the grating into the first diffraction order back into the half-space, and within the pattern at least one of the following properties of the grating reflectors is varied to produce the image: diffracting property of the gratings, position of the gratings relative to the respectively associated microreflector, reflecting property of the microreflectors.

[0013] According to the invention, the microstructures are thus no longer configured as micro picture elements having a separate microreflector. Instead, microstructures and microreflectors are combined into grating reflectors having at least one reflective grating and an associated microreflector, wherein the grating configuration and the geometry of the microreflector are so chosen that the first diffraction order is reflected on the grating and thrown back into the half-space by the microreflector, preferably being concentrated. The return radiation depends on the configuration of the grating reflector with regard to direction in which it is emitted, angle of radiation and color. Through the arrangement of differently configured grating reflectors in the pattern there can be produced colored symbols or images.

[0014] From a viewing direction a viewer perceives an individual grating reflector differently in intensity and/or color, but without picture information. Departing from the prior art, the picture information does not come from the microstructuring itself, since a reflective grating per se supplies no picture information. The picture information is instead obtained by the interaction of a plurality of grating reflectors of different configuration (combination of microreflector and microstructure in the respective grating reflector), so that between the grating reflectors there is effectuated a color difference or intensity difference which as a whole produces the perceptible image.

[0015] Since the reflective gratings in combination with the microreflectors normally possess strongly angular-dependent properties, there can also be produced parallax images as with a moiré magnification arrangement.

[0016] By a suitable configuration it is also possible to produce a stereoscopic effect, by adjusting the direction in which microreflectors reflect back, and preferably concentrate, radiation diffracted by the grating into the first diffraction order such that some grating reflectors supply picture information for the left eye and others for the right eye (in accordance with the visual-angle difference).

[0017] The picture information is normally produced by the security element by each grating reflector consisting of microreflector and grating(s) having the function of a pixel for image production.

[0018] The security element can be manufactured in a single molding process. No molding steps to be performed in mutual register on different sides of a foil are required. It is instead possible to design a substrate, e.g. a foil, with a single embossing process such that the structures of both the microreflectors and the gratings are produced. The relative position (and shape) of grating and associated microreflector is predetermined by the corresponding embossing tool, so that it is no longer necessary to perform a series of processing steps involving mutual register on the substrate. Manufacture is thus drastically simplified compared with the stated generic security elements.

[0019] Further, the minimum thickness of the security element is no longer predetermined by a focal length of focusing elements. The security element can be configured considerably thinner than was possible in the prior art. The thickness is restricted solely by the depth of the microreflectors. Said depth corresponds approximately to the height that microlenses of known moiré magnification arrangements have, which leads to the result that the minimum thickness of the security element amounts to only a fraction of that of conventional security elements with moiré magnification arrangements. Nevertheless, a moiré effect can be realized equally well.

[0020] The gratings that are associated with the microreflectors and lie for example on the bottom of a concave mirror or of a mirror trough are reflective gratings. They reflect the first diffraction order toward the associated microreflector. This is a fundamental difference over the absorbent structures known in the prior art which, as moth-eye structures or also as regular subwavelength structures, are to produce reflexes as small as possible to effectuate a good contrast in a microimage.

[0021] Preferably, the gratings are so configured here that diffraction orders higher than the ± 1st diffraction order are, if possible, not reflected toward the microreflector or reflected at angles so flat that the microreflector only directs radiation intensity of the higher diffraction orders into the half-space to a smaller extent than radiation that was diffracted into the ± 1st diffraction order. Further, it is preferable that the intensity of the radiation diffracted into the ± 1st diffraction order lies above the intensity of the radiation diffracted into the 0th diffraction order.

[0022] For certain arrangements it can be advantageous if one of the two ± 1st diffraction orders is preferred. This can be obtained by a so-called blazed grating, which supplies an asymmetry between −1st and +1st order.

[0023] The microreflectors can be configured as trough-shaped reflectors. They are then concave troughs which preferably have a plane bottom. The plane bottom need not necessarily be reflective. On the plane bottom there is disposed the grating, which is then likewise configured as a linear grating. In particular with trough-shaped reflectors it is also possible to dispose more than one grating along the concave troughs of the reflector. Optionally, the microreflectors can be designed as concave concave mirrors, which preferably have a plane bottom on which the grating lies. Here, too, the bottom need not be reflective. The microreflectors can of course also be realized by non-concave concave mirrors or troughs. The plane bottom of the microreflectors can in particular be configured obliquely, so that the grating is inclined toward the microreflector.

[0024] Alternatively, there can also be used microreflectors whose bottom is not plane, but for example of bulged configuration.

[0025] Using the individual grating reflectors as pixels is especially simple when the microreflectors are configured as concave concave mirrors which are rotationally symmetric, having for example the form of the surface area of a spherical segment or ellipsoid segment. Such a surface area is obtained when a segment is cut out from an ellipsoid or sphere through two parallel planes truly intersecting the sphere or ellipsoid.

The smaller one of the two parallel circular areas or ellipses arising from the section then constitutes the bottom of the concave concave mirror. It does not have to be mirror-coated.

[0026] For conventional optical embodiments it is preferred that the microreflectors have a depth of 2 to 30 μm, preferably 5 to 20 μm. Further, it is preferred that each grating has a grating period between 0.3 μm and 1 μm. Such structure dimensions yield good results at the same time as simple manufacturability.

[0027] If the security element is designed such that each grating reflector acts as a pixel, it is preferred to configure the microreflector as a rotationally symmetric concave mirror, as mentioned hereinabove. The grating can then be a circular grating. The perceptible properties of each pixel are then adjusted e.g. by the position of the circular grating on the bottom of the concave mirror.

[0028] Depending on the lateral position of the grating in the respective microreflector, the individual pixel to which the grating reflector then corresponds has a different intensity in the image.

[0029] Grating reflectors with circular apertures are preferably disposed in a hexagonal pattern, since there can then be achieved an area fill as high as possible.

[0030] The individual grating reflectors can be configured with bars surrounding them, i.e. at least some neighboring grating reflectors then do not abut each other directly, but are separated by a bar. Consequently, there are bar areas between the grating reflectors. Through the structuring of the coating of the bar areas and/or the design of the thickness of the substrate in the region of the bar areas one can ensure that the bar areas reflect and/or transmit incident light differently. The effect is preferably designed to be laterally variable in order to additionally encode symbols and make them visible in transmission. Thus, additional anti-forgery security is obtained.

[0031] A laterally varying coating of the bar areas is preferably realized by the bar areas first being furnished with a coating, for example with a metallization, and said coating being removed again regionally, e.g. by an etching method. Alternatively, it is possible to regionally transfer the coating present in the bar areas by laminating with an acceptor foil, and thus regionally remove it from the bar areas. Further details on such a transfer method can be found in the print WO 2011/138039 A1.

[0032] An especially good efficiency of the ± 1st diffraction order is obtained when microreflectors and gratings are coated metallically on their side facing the half-space, preferably with aluminum, silver, gold, copper, chromium or an alloy containing one or more of said metals. The microreflectors and gratings can also be realized by high-refractive dielectrics, such as e.g. TiO_2 or ZnS, or semimetals such as silicon and germanium. In particular, the gratings can be configured as such by said materials. Further, said materials can serve as a reflective coating of the microreflectors.

[0033] The microreflectors can have in principle any arbitrary shape in their apertures (openings), for example square, circular or rectangular apertures.

[0034] The security element can be configured in particular as a security thread, pull thread, security band, security strip, patch or as a label. In particular, the security element can cover transparent regions or recesses of an object to be protected.

[0035] The security element can in particular be part of a precursor, not yet fit for circulation, of a value document which can for example also have additional authentication features (such as e.g. luminescent substances provided in the volume, etc.). Value documents are understood here to be documents having the security element, on the one hand, but value documents can also be other documents or objects that can be furnished with the security element according to the invention in order to have uncopiable authentication features, on the other hand. Chip cards or security cards, such as e.g. bank cards or credit cards, are further examples of a value document.

[0036] For the manufacturing method according to the invention there come into consideration in particular direct exposure techniques, e.g. using a laser writer. Manufacture can be effected analogously to known manufacturing methods for microlenses. The original of the structure is written via direct exposure using a laser writer into a substrate coated with photoresist, and subsequently the exposed portion of the photoresist removed. An exposed original can subsequently be electroformed and thus an embossing stamp produced. Finally, the structure is replicated for example in UV lacquer on foil via an embossing process. Alternatively, a nanoimprinting process can be used. More elaborate methods for manufacture of originals such as electron-beam or focused-ion-beam exposure methods allow an even finer configuration of the geometry.

[0037] The manufacturing method according to the invention can be configured such that the described preferred configurations and embodiments of the security element are manufactured.

[0038] It will be appreciated that the features mentioned hereinabove and those to be explained hereinafter are usable not only in the stated combinations but also in other combinations or in isolation without going beyond the scope of the present invention.

[0039] Hereinafter the invention will be explained more closely by way of example with reference to the attached drawings, which also disclose features essential to the invention. For better illustration, the representation in the figures is not true to scale or to proportion. There are shown:

Fig. 1 a schematic representation of a security element,

Figs. 2a and b illustrations of the reflections that can occur with the security element of Fig. 1,

Figs. 3a and 3b schematic representations similar to Fig. 1 for illustrating different grating structures that can be used with the security element of Fig. 1, Figs. 4, 5 and 6 diffraction efficiencies for the different grating structures that can be employed in the security element of Fig. 1,

Figs. 7a-i schematic illustrations of the reflections that occur with a first embodiment of the security element,

Figs. 8, 9 and 10 representations similar to Fig. 7 for further embodiments of the security element,

Fig. 11 a plan view of a security element similar to that of Fig. 1 with modifications with regard to forms of reflectors and grating structures,

Fig. 12 a plan view similar to Fig. 11, but with reflectors and grating structures having a circular aperture,

Fig. 13 a plan view of a security element with an arrangement of linear gratings and trough-shaped reflectors that are respectively configured similar to the design of Fig. 11 and produce an image stereoscopically,

Fig. 14 an arrangement of linear gratings with trough-shaped reflectors for representing a motif likewise for stereoscopic image production,

Fig. 15 a representation similar to Fig. 1 for a development of the security element shown there, and

Fig. 16 a plan view of the security element of Fig. 15.

[0040] Fig. 1 shows schematically in the upper part a sectional representation of a security element 1 and in the lower part the appurtenant plan view thereof. The security element 1 is made of a foil 2 having an embossed structure 3 formed on its upper side (this term being intended to be purely exemplary and not to state any preferential direction). The embossed structure 3 comprises a multiplicity of reflectors 4, which are designed as elliptical reflectors with a plane bottom 5 in this exemplary embodiment. On the bottom 5 of each reflector 4 there is located a reflective grating 6. The total embossed structure 3 is overlaid with a metal layer. The metal layer thus covers both the concave area defining the reflecting properties of the reflector 4, and the grating 6.

[0041] One grating 6 forms with the associated reflector 4 a grating reflector 7 in each case. Each grating reflector 7 throws radiation incident on the aperture 8 of the grating reflector 7 back from the upper side in concentrated form into the half-space from which the radiation came. The direction and intensity depend on the configuration of the grating reflector 7.

[0042] Fig. 1 makes clear that a multiplicity of reflectors and gratings are present in the security element, with one grating 6 being associated with one reflector 4 in each case in this exemplary embodiment. This is obtained by the grating 6 being disposed on the bottom 5 of the corresponding reflector 4. The grating reflectors 7 are disposed in a pattern which is configured as a side-by-side array of the grating reflectors 7 in simplified form in the plan view which is to be seen in the lower part of Fig. 1. Within the pattern the design of the grating reflectors 7 varies, so that each grating reflector 7 forms a pixel of a motif characterizing the security element 1. For the variation of the grating reflectors 7 there are different possibilities which will be explained hereinafter. In the embodiment of Fig. 1, the position of the grating 6 on the bottom 5 varies by way of example.

[0043] Between the grating reflectors 7 there is a distance, in the representation of Fig. 1, which leads to bar areas 11 being formed on the substrate which lie between the edges of neighboring grating reflectors 7. Said bar areas can be used for encoding a further optical effect, as to be explained hereinafter with reference to the design of Figures 15 and 16. In the embodiment of Fig. 1, however, the bar areas are without any further importance.

[0044] For the reflection of illumination radiation that is incident from above relative to the sectional representation in the upper part of Fig. 1, what is essential is the reflection of the radiation that the grating 6 backscatters, as will be explained. Said reflection is effected on the respective reflector 4. The term "reflector" thus does not relate to a direct reflection of the incident illumination radiation, as would be the case e.g. with a retroreflector, but rather to the reflective property that the reflector 4 has for radiation diffracted back by the grating 6.

[0045] This effect can be readily recognized in Fig. 2, which shows in its partial Figures 2a and 2b how incident radiation 9 is diffracted by the grating 6 toward the reflector 4 and reflected there, preferably concentrated, so that it is thrown back again as return radiation 10 into the half-space from which the incident radiation 9 came. Fig. 2a shows the relations for the 2nd diffraction orders, and Fig. 2b represents the corresponding 1st diffraction order. The − 2nd and − 1st orders would only be shifted relative to the axis of symmetry of the reflector and of the grating if the grating 6 were disposed symmetrically on the bottom 5, as is the case in the simplified representation of Fig. 2. For the sake of simpler explanation, Fig. 2 assumes a rotationally symmetric reflector 4, and the geometry of the reflector 4 is so chosen that the 1st diffraction order of the visible spectrum is reflected and concentrated.

[0046] In the example, the reflector 4 possesses an elliptical geometry with an aperture of 11.4 µm, an apex of 12.8 µm and a grating disposed in the center at a depth of 11.4 µm. The grating period amounts to 800 nm.

[0047] For a wavelength of 520 nm the above-mentioned ± 2nd and ± 1st diffraction orders are present, for which Figs. 2a and 2b show the marginal rays of the incident radiation 9 for which return radiation 10 arises, and of the return radiation 10. Due to the rotational symmetry it is possible to replace the statement of a solid angle by a plane angle for the incident radiation 9 and the return radiation 10. In the case of the ± 2nd diffraction order, the aperture angle of the incident radiation (also called acceptance angle) amounts to 9°. This light is converted as return radiation 10 to an exit angle range of 3.7°. For the ± 1st order, the aperture range of the incident radiation amounts to 31.5°, and the exit angle range 17.3°.

[0048] For the security element 1 of Fig. 1 it is desirable to maximize the efficiency of the 1st diffraction order while, on the other hand, suppressing other diffraction orders if possible, i.e. not converting them to return radiation 10. This can be obtained e.g. by a suitable choice of the grating 6. If there is chosen for example, for the mentioned grating with a period of 800 nm, aluminum as the material with a one-to-one bar-to-gap ratio as well as a bar height of 150 nm, the efficiency, i.e. backscatter intensity, of the ± 1st diffraction order will be considerably greater than that of other diffraction orders.

[0049] With a grating having a rectangular bar profile, negative and positive diffraction orders are the same, since the grating is symmetric (always based on the case that the grating is disposed symmetrically on the bottom 5). The preference of a direction can be obtained by an asymmetric grating profile, as is known in the prior art as a blazed grating. The corresponding relations are represented by way of example in Figs. 3a and 3b. Here, Fig. 3a shows a rectangular grating in which − 1st and + 1st orders are configured symmetrically, i.e. both equally strong. If a blazed grating is employed, one order is preferred and the other suppressed. This is obtained e.g. by the asymmetric triangular form of the grating bars. Other possibilities for producing an asymmetric preference of negative or positive diffraction orders are so-called Dammann gratings or slanted gratings.

[0050] In principle, with the reflective grating 6 the intensity of the ± 1st order in the visible spectral region can lie above the intensity of the 0th diffraction order, i.e. of the mirroring return radiation. Figs. 4a and 4b show the diffraction efficiencies of the - 1st and 0th diffraction orders of a grating with a period of 550 nm in the visible spectral region for different angles of incidence; Fig. 4a the efficiency of the 1st diffraction order, Fig. 4b that of the 0th diffraction order. The reflective grating here is one with a rectangular profile consisting of aluminum bars which have a width of 275 nm and a height of 120 nm and are disposed in a grating period of 550 nm.

[0051] Figs. 5a and 5b show an analogous representation for a grating with a grating period of 650 nm and aluminum bars with a width of 325 nm and a height of

120 nm. These efficiencies obtained here already suffice for use as a reflective grating in a security element 1 according to Fig. 1.

[0052] Further improved diffraction efficiencies are shown by a blazed grating according to Fig. 3b, as evidenced by the plottings in Figs. 6a and 6b, which correspond to those of Figs. 4a and 4b. The grating period again amounts to 550 nm and the maximum height of the triangular profile of the aluminum bars 340 nm. Comparison with Fig. 4 shows that the efficiency of the − 1st order is raised further.

[0053] Figs. 7a-c, d-f and g-i show the reflection of the 1st diffraction order for different wavelengths of the incident radiation. Figs. 7a, 7d and 7g shows the relations with blue light (wavelength 450 nm), Figs. 7b, 7e and 7h with green light (wavelength 520 nm), and Figs. 7c, 7f and 7i the relations with red light (wavelength 700 nm). The relations between Figs. 7a-c, 7d-f and 7g-i differ with regard to the depth of the reflectors. All reflectors have an aperture of a =12 µm. In Figs. 7a-c the depth amounts to 9 µm, in Figs. 7d-7f to 12 µm and in Figs. 7g-7i to 15 µm. The apex of the reflectors amounts to 10.5 µm (Figs. 7a-c), 13.5 µm (Figs. 7d-7f) and 16.5 µm (Figs. 7g-7i). The grating parameters correspond to those of Fig. 4. The grating period accordingly amounts to 550 nm. The entry angles for incident radiation 9 and exit angles for emergent radiation 10 for Figs. 7a-7i are summarized in the following table:

Figure	Acceptance angle	Exit angle
a	25.0	28.1
b	26.0	29.6
c	17.5	18.5
d	31.5	17.2
e	29.5	14.9
f	10.5	4.1
g	31.5	6.4
h	25.4	2.8
i	5.5	1.1

[0054] The stated numbers are in degrees, and show that with increasing structure depths, i.e. depths of the reflector 4, the divergence of the return radiation 10 decreases, i.e. return radiation 10 is concentrated increasingly toward the viewer, since the exit angle describes the concentration. Greater wavelengths moreover restrict the acceptance angle of the incident radiation 9.

[0055] The variation of the reflecting properties of the reflectors 4 as performed in Fig. 7, explained by way of example with reference to the reflector depth, is a first possibility for changing the reflecting property of the grating reflectors 7, for thereby modulating the pattern of grating reflectors 7 and for finally producing picture information.

[0056] A variation of the reflecting properties can also be obtained by the variation of other geometrical parameters of the grating reflectors 7 consisting of grating 6 and reflector 4. Fig. 8 shows representations similar to those of Fig. 7, whereby not the depth of the reflectors is varied as in Fig. 7, but rather the size of the aperture. It amounts to 9 μm in Figs. 8a-c, 12 μm in Figs. 8d-f, and 15 μm in Figs. 8g-i. The wavelengths that are represented correspond to those of Fig. 7. The reflector depth is constant at 12 μm in all arrangements, the apex amounts to 13.5 μm. The grating period amounts to 550 nm. The corresponding acceptance angles for incident radiation 9 and exit angles for return radiation 10 are as follows:

Figure	Acceptance angle	Exit angle
A	30.5	7.5
B	23.5	8.4
C	4.5	4.7
D	31.5	17.2
E	29.5	14.9
F	10.5	4.1
G	26.5	9.4
H	27.5	9.5
I	16.0	2.3

[0057] It is apparent that greater apertures do not substantially worsen the concentration of the return radiation 10. On the other hand, the area of the bottom 5 and thus the area available for the grating 6 grows with increasing aperture. As in Fig. 7 as well, the exit angle of the return radiation 10 decreases with growing wavelength.

[0058] The variation of the aperture is a second possibility for modulating the pattern of grating reflectors 7.

[0059] In Figs. 7 and 8 the reflecting properties of the reflectors 4 were varied. However, it is also possible to vary the diffracting properties of the grating in order to vary the acceptance angle of the incident radiation 9 and/or the exit angle of the return radiation 10. Fig. 9 shows a representation similar to Fig. 7, with the grating period now being varied between Figs. 9a-c, 9d-f, and 9g-i. The reflector geometry, on the other hand, is constant, at least for the cases shown in Figs. 9d-f and Figs. 9g-i, with an aperture of 12 μm, a depth of 12 μm and an apex of 13.5 μm (Figs. 9a-c), 15 μm (Figs. 9d-f) and 15 μm (Figs. 9g-i). In Figs. 9a-c the grating period amounts to 400 nm, in Figs. 9d-f 600 nm and in Figs. 9g-i 800 nm. The represented colors in Figs. 9a-i also correspond to those of Figs. 7a-i and 8a-i. The corresponding values for the acceptance angle and the exit angle are the following:

Figure	Acceptance angle	Exit angle
A	19.0	7.7
B	9.0	3.7
C	0.0	0.0
d	31.5	8.8
e	32.0	9.7
f	16.5	8.9
g	32.0	8.9
h	31.5	8.7
i	32.0	9.6

[0060] The variant of Figs. 9a-c shows no reflection of red light. Blue or green light, on the other hand, is directed toward the viewer in concentrated form by the reflector 4, since the exit angle is considerably smaller than the acceptance angle. The two other cases (Figs. 9d-f and 9g-i) show no significant difference for blue and green light. The acceptance angle of red light increases considerably for the greater grating period.

[0061] The variation of the grating parameters is a third possibility for modulating the pattern of grating reflectors 7.

[0062] The way the return radiation 10 is produced from the incident radiation 9 may be due not only to the reflecting properties of the microreflectors or the diffracting properties of the grating 6, but also to the position of the grating 6 relative to the respectively associated reflector 4. Fig. 10 shows a variation in this regard, with the grating 6 being shifted to the left on the bottom 5 relative to the axis of symmetry of the reflector 4 in Figs. 10a-c, the grating lying symmetrically to the axis of symmetry but not covering the total bottom 5 in Figs. d-f, and the grating 6 being shifted to the right on the bottom 5 in Figs. 10g-i. In this exemplary embodiment the shift amounts to − 1.6 μm (Figs. 10a-c), 0 μm (Figs. 10d-f) and 1.6 μm (Figs. 10g-i). The reflector geometry is constant in all cases with an aperture of 12 μm, an apex of 13.5 μm and a depth of 12 μm. The grating period amounts to 550 nm. The colors on which the representation of Figs. 10a-i is based correspond to those of Figs. 7, 8 and 9. For the individual colors and arrangements there thus results the following:

Figure	Acceptance angle	Exit angle
A	37.5	15.0
b	35.0	12.4
c	16.0	6.0
d	31.5	17.2
e	29.5	14.9
f	10.5	4.1
g	26.5	12.9
h	23.5	10.7
i	4.5	2.0

[0063] The representations of Fig. 10 are based on a microreflector with an aperture of 12 μm and a depth of 12 μm.

[0064] Fig. 10 shows that a link shift of the grating increases the acceptance angle for incident radiation 9 and thus the reflected light intensity of the − 1st order. The divergence of the return radiation 10, on the other hand, is influenced by the different position of the grating considerably less.

[0065] The variation of the position of the grating 6 relative to the reflector 4 is a fourth possibility for modulating the pattern of grating reflectors 7.

[0066] In the above examples, reflectors with elliptical geometries have been examined and represented. It is of course possible to optimize the light concentration of a certain color toward the viewer by a different geometry, so that a viewer perceives this color dominantly.

[0067] Further, parameters other than those represented are also suitable and employable in embodiments for influencing the diffracting properties of the gratings or the reflecting properties of the microreflectors. Besides the curvature of the reflectors 4 being varied, the geometry of the reflectors 4 can also be designed asymmetrically. Further, besides the period being varied, the profile of the grating 6 can also be varied to achieve a locally varying total reflection behavior of the respective grating reflectors consisting of reflector and grating. Moreover, it is possible to configure the bottom 5 obliquely, i.e. to incline the grating toward the reflector 4 in a location-dependent manner.

[0068] The stated possibilities can of course also be combined at will.

[0069] Thus, a multiplicity of parameters come into consideration for designing the return radiation 10 differently in a location-dependent manner within the pattern and thus modulating the radiation backscattered by the grating reflectors 7 within the pattern in the security element 1 according to the invention.

[0070] As a grating there can not only be employed one-dimensionally periodic gratings, and they need also not be combined with reflectors that are curved in the same spatial direction. Gratings 6 are also possible that are rotated around an axis of symmetry of the reflector 4, and the rotation is varied within the pattern for modulation. For two-dimensional periodic gratings 6 cross gratings are particularly suitable, the periodicity preferably extending perpendicular to the curvatures of a reflector with a rectangular aperture. Circular gratings are particularly suitable for reflectors with circular apertures, on the other hand. Mixed forms or elliptical gratings in reflectors with elliptical apertures are of course also possible.

[0071] For producing the motifs, grating reflectors 7 respectively formed from grating and reflector are disposed side by side, with their configuration varying laterally to form an image for example as a colored symbol. The variation of the diffracting properties of the gratings 6, or of the position of the gratings 6 relative to the respective associated reflector 4 or of the reflecting property of the reflectors 4 or of a combination therefrom, effectuates a color contrast or intensity contrast in the motif. Since the gratings 6 moreover possess strongly angular-dependent properties, the motifs can be employed for producing parallactic images, as mentioned hereinabove. It is thereby possible to implement both parallactic motions and spatial effects.

[0072] Fig. 11 shows a simple example of a plurality of grating reflectors 7 in plan view, whose gratings 6 are configured as linear gratings and are combined with trough-shaped reflectors 4. The trough-shaped reflectors 4 lie side by side periodically. The gratings 6 are shifted toward the reflector laterally, the shift being continuous and coming about in the exemplary embodiment through an about 15% smaller frequency of the individual gratings relative to the frequency of the reflectors 4. A viewer will perceive the individual grating reflectors consisting of reflector and grating with different brightness, resulting in an intensity modulation for the individual strips.

[0073] Outside the optically active grating, the bottom can be plane or also be furnished with a (light-absorbing) moth-eye structure or a subwavelength structure. The latter variants improve the contrast, since the specular reflection is suppressed as a result.

[0074] Further, in a typical viewing situation the perception will be different for the left eye and the right eye due to the different viewing angles, which can be used for a stereoscopic effect, as to be explained.

[0075] A lateral variation can of course also be achieved by two-dimensional grating reflectors 7. Fig. 12 shows a representation that is similar to the lower part of Fig. 1. Here, rotationally symmetric reflectors 4 are combined with circular gratings 6, with the individual gratings 6 being shifted differently within the associated reflector 4. For a viewer, the individual grating reflectors 7 will differ in brightness, since they concentrate the incident radiation toward the viewer to different extents at a given viewing angle. An especially high area coverage is obtained with the grating reflectors 7 when they are disposed in a hexagonal pattern. Each individual grating reflector 7 realizes a pixel, i.e. an image point, so that the variation of the stated property, in this case of the position of the grating 6 relative to the respectively associated reflector 4, modulates the image.

[0076] A stereoscopic perception requires two images; one image for the left eye and another for the right one. Such stereoscopic images can likewise be produced with the security element 1 according to Fig. 1. The light is then so directed in different directions through the variation of the properties that a different modulation is obtained for the left eye and the right eye. Fig. 13 shows an exemplary arrangement of linear gratings 6 in trough-shaped reflectors 4, with the gratings 6 being tilted relative to each other and having different periods. The different grating periods effectuate a color effect of the structure. The grating reflectors 7 located on the left side preferably direct the incident radiation in the direction of the left eye of a viewer, while the grating reflectors on the right subject the right eye to return radiation 10. The color impression is varied by the choice of different grating periods or reflector geometries. The arrangement of the grating reflectors 7 according to Fig. 13 thus allows both spatial effects and kinetic effects to be represented.

[0077] A simple embodiment exemplifying this principle is shown in Fig. 14. The area of the two letters "AB" is filled with a multiplicity of grating reflectors 7. The grating reflectors are so oriented in the letter "A" that they preferably direct the light toward the left eye. The light from the letter "B", on the other hand, will be perceived primarily by the right eye. If the grating reflectors 7 have an accordingly small design, i.e. the pixelation is accordingly small, the two symbols can also be present in mutually interlaced form.

[0078] Fig. 15 shows an exemplary embodiment similar to that of Fig. 1. Accordingly, the reference signs for functionally or structurally identical elements are also taken from Fig. 1. In the security element 1 of Fig. 15, a pattern of grating reflectors 7 is likewise employed. Between neighboring grating reflectors 7 there remain bars in the substrate, which result in bar areas 11 lying between the individual grating reflectors 7. The bar areas are structured laterally in the design of Fig. 15 such that some bar areas 11 are furnished with a metallization 12 while others are not. Fig. 16 shows this state in a plan view similar to the view of Fig. 12.

[0079] The only regional metallization of the bar areas 11 creates regions I and II in which the bar areas with a metal layer 12 (regions I) and without a metal layer (regions II) are provided. The metallization has the consequence that incident radiation 9 falling on a metallized bar area 11 is thrown back as a reflex 13. In the regions II where the bar areas 11 are not metallized, on the other hand, the incident radiation is not reflected. The security element 1 is thus subdivided into regions I and II which differ in their reflection behavior and also in their transmission behavior. By lateral structuring of the metallization it is thus possible to encode additional information in the security element 1. Instead of a metallization there can also be employed a different kind of reflective layer.

[0080] Instead of a metallization or reflective layer there can be formed an absorbent layer; the lateral structuring of the bar areas 11 then does not affect the reflection behavior, but the transmission behavior.

[0081] A further possibility of influence is likewise indicated in Fig. 15. What is involved here is the thickness of the bars under the bar areas 11, i.e. the thickness of the substrate 2 in the region of the bars 11. In Fig. 15 the bars are less thick in the region of the bar areas in the regions I than in the regions II by way of example. If the substrate is suitably chosen, this can likewise influence the transmission behavior. The different height of the plateaus on which the bar areas 11 lie results automatically, in the design of Fig. 15, when grating reflectors 7 with different depth are formed, and the bottoms 5 lie at a level. The different depth of the grating reflectors 7, for example in the regions I and II, then leads automatically to a different thickness of the substrate in the region of the bar areas 11. As to be explained more closely hereinafter, a different height of the plateaus on which the bar areas 11 lie can also be used advantageously in the production of the laterally varying coating.

[0082] The bar areas 11 always arise when grating reflectors do not abut each other seamlessly. The total area of the bar areas 11 thus depends on the pattern in which the grating reflectors 7 are disposed. If they are disposed in the form of a hexagonal pattern with a high area coverage, as in Fig. 12 for example, the total area of the bar areas 11 is very small. With rectangular apertures of the grating reflectors, the total area of the bar areas 11 can be made arbitrarily small. If a distance is deliberately left between the grating reflectors, as in Fig. 16, the total area of the bar areas 11 increases. This measure makes it possible to adjust in a targeted manner the transmission effect or reflective effect that is effectuated by the bar areas 11. In other words, the clarity with which a symbol or image is recognizable through the lateral structuring of the bar areas 11 can be adjusted by accordingly choosing the total area of the bar areas through the distance of the grating reflectors 7.

[0083] The principle employed in the security element 1 of Fig. 1 supplies a large construction kit for designing patterns or symbols by grating reflectors 7. The variation of the grating reflectors 7 in the pattern can be realized by many parameters.

[0084] The structure of the security element 1 can be manufactured very simply by a single embossing process. For this purpose one requires only a corresponding embossing tool that has a corresponding negative form for each grating reflector 7, i.e. produces both the reflectors 4 and the gratings 6. To obtain a high yield of the grating reflectors 7, the gratings 6 must be precisely formed in the embossing tool. The manufacture of the embossing tool can be obtained using electron-beam writing systems or interferometric methods.

[0085] The reflectors 4 typically have a depth of 2 to 30 μm, a particularly preferred range lying between 5 and 20 μm. Smaller depths are advantageous with regard to both the manufacture of the embossing tool and later duplication. However, the grating 6 produces its optical effect only when at least 4 to 10 grating periods can be accommodated on the bottom 5. This gives a lower limit for the size of the reflectors 4. An upper limit results when the grating reflectors 7 are intended to be used as pixels, which should naturally be as small as possible and in particular should no longer be resolved with the unarmed eye. On the other hand, as flat an embossing as possible is advantageous for duplication.

[0086] For producing the embossing tool, the reflectors 4 are preferably first produced, for example photolithographically by direct laser writing. Independently thereof, the structure of the gratings 6 is produced. These two operations are preferably performed in an accurately fitting manner in one and the same photoresist which, as a template, is the basis for the embossing tool. Alternatively, two different photoresist coating operations are also possible.

[0087] Also, it is possible in a variant to first produce a homogeneous grating, coat it with photoresist and then produce laterally differently configured microreflectors, for example by laser writing. For this purpose, a grating is first manufactured for example using an electron-beam exposure method, and molded. Subsequently, said grating substrate is coated with a photoresist in sufficient thickness, e.g. 10 μm. Then, reflectors 4 are exposed with a laser writer by the direct exposure method, so that the grating 6 lies open in the middle of the individual reflectors after developing.

[0088] The employed laser writers can operate with two-photon absorption processes. It is then possible to produce reflectors 4 and gratings 6 in a single process.

[0089] The template manufactured for the embossing tool is now copied galvanically or by a nanoimprinting process.

[0090] Since in the embossing of a foil a multiplicity of security elements are usually to be produced in one embossing step, it is preferable to provide a plurality of mutually adjacent stamp elements in the embossing tool which have respectively been produced from a template in the previously described manner.

[0091] The embossed foil is preferably overlaid with an opaque metal layer. This may be done by sputtering, electron-beam vapor deposition or thermal evaporation. Particularly suitable metals are aluminum, silver, gold, nickel or chromium or alloys of said materials. The thicknesses of the metal layer lie between 20 and 100 nm. The metal surface is then finally preferably overlaid with a protective layer or laminated with a cover foil.

[0092] Here, a further advantage of the security element over known moiré arrangements becomes apparent, since the microlenses usually employed there cannot be overlaid with a cover layer. Their optical imaging property would thereby be lost.

[0093] For producing a laterally structured coating of the bar areas 11, a corresponding coating is preferably first applied to all bar areas 11 and then removed from some bar areas again. In the case of a metallization, removal is effected by a suitable demetallization method. In particular an etching process or a transfer method according to WO 2011/138039 A1 can be used here. It is also possible to remove the coating, for example a demetallization, by means of ultrashort-pulse lasers and the use of a writing laser beam.

[0094] Upon the removal of the coating, the latter can be prevented in a targeted manner from also being removed in the region of the grating reflectors 7 or in the regions I. Thus, it is possible for example to fill the metallized embossed structure 3 completely with a photoresist, i.e. to flatten it out. Then one can etch the photoresist for example up to the levels of the higher bar areas 11 (regions II) and remove the thus laid-open coating, for example etch a metal layer. A subsequent removal of the photoresist then lays open the grating reflectors 7 as well as the bar areas 11 with the metallization 12 lying at a lower level (regions I) again, which in this way are not affected by the intervention on the bar areas 11 in the regions II.

List of reference signs

1 Security element
2 Foil
3 Embossed structure
4 Reflector
5 Bottom
6 Grating
7 Grating reflector
8 Aperture
9 Incident radiation
10 Return radiation
11 Bar area
12 Metallization
13 Reflex
I, II Region

Claims

1. A security element for an object to be protected which has a substrate with a plurality of microreflectors disposed in a pattern and a plurality of microstructures which together with the microreflectors produce an image perceptible to a viewer, wherein:

- each microstructure is configured as a reflective grating and associated with one of the microreflectors, thereby forming grating reflectors each consisting of one microreflector and at least one grating,
- each grating is so configured that it diffracts visible radiation incident from a half-space into a first diffraction order and toward the associated microreflector,
- in each grating reflector the grating and the microreflector are matched to each other such that the microreflector reflects radiation diffracted by the grating into the first diffraction order back into the half-space as return radiation, and
- within the pattern at least one of the following properties of the grating reflectors varies to produce the image: diffracting property of the gratings, position of the gratings relative to the respectively associated microreflector, reflecting property of the microreflectors.

2. The security element according to claim 1, wherein the microreflectors are respectively configured as concave mirrors or concave troughs with a plane bottom, wherein the grating is disposed on the plane bottom.

3. The security element according to claim 2, wherein the plane bottom of the microreflectors is configured obliquely, so that the grating is inclined toward the microreflector.

4. The security element according to claim 2 or 3, wherein the microreflectors are respectively configured as concave mirrors which are rotationally symmetric.

5. The security element according to any one of claims 1 to 4, wherein the microreflectors have a depth of 2 μm to 30 μm.

Date Reçue/Date Received 2020-10-08

6. The security element according to any one of claims 1 to 5, wherein each grating has a grating period between 0.3 µm and 1 µm.

7. The security element according to any one of claims 1 to 6, wherein the gratings are configured as blazed gratings.

8. The security element according to any one of claims 1 to 7, wherein the microreflectors and gratings are coated metallically on their side facing the half-space.

9. The security element according to any one of claims 1 to 8, wherein the property of the grating reflectors so varies within the pattern that an image is produced by means of a moiré effect.

10. The security element according to any one of claims 1 to 9, wherein a bar area is formed at least regionally between neighboring grating reflectors, wherein there are present in the pattern a plurality of bar areas which differ with regard to a surface coating.

11. A security paper or value document, characterized by a security element according to any one of claims 1 to 10.

12. A method for manufacturing a security element for an object to be protected wherein there are formed on a substrate a plurality of microreflectors disposed in a pattern and a plurality of microstructures which together with the microreflectors produce an image perceptible to a viewer, wherein:

- each microstructure is configured as a reflective grating and associated with one of the microreflectors, thereby forming grating reflectors each consisting of one microreflector and at least one grating,
- wherein each grating is so configured that it diffracts visible radiation incident from a half-space into a first diffraction order and toward the associated microreflector,

Date Reçue/Date Received 2020-10-08

- in each grating reflector the grating and the microreflector are matched to each other such that the microreflector reflects radiation diffracted by the grating into the first diffraction order back into the half-space as return radiation, and
- within the pattern at least one of the following properties of the grating reflectors is varied to produce the image: diffracting property of the gratings, position of the gratings relative to the respectively associated microreflector, reflecting property of the microreflectors.

13. The method according to claim 12, wherein the microreflectors are respectively configured as concave concave mirrors or concave troughs with a plane bottom, wherein the grating is disposed on the plane bottom.

14. The method according to claim 13, wherein the plane bottom of the microreflectors is configured obliquely, so that the grating is inclined toward the microreflector.

15. The method according to claim 13 or 14, wherein the microreflectors are respectively configured as concave concave mirrors which are rotationally symmetric.

16. The method according to any one of claims 12 to 15, wherein the microreflectors are configured with a depth of 2 μm to 30 μm.

17. The method according to any one of claims 1 to 16, wherein each grating is configured with a grating period between 0.3 μm and 1 μm.

18. The method according to any one of claims 12 to 16, wherein the gratings are configured as blazed gratings.

19. The method according to any one of claims 12 to 18, wherein the microreflectors and gratings are coated metallically on their side facing the half-space.

20. The method according to any one of claims 12 to 19, wherein the property of the grating reflectors is so varied within the pattern that an image is produced by means of a moiré effect.

Date Reçue/Date Received 2020-10-08

21. The method according to any one of claims 12 to 20, wherein the grating reflectors are so disposed that a bar area is formed at least regionally between neighboring grating reflectors, wherein there are provided in the pattern a plurality of bar areas which differ with regard to a surface coating.

22. The method according to claim 21, wherein the bar areas are first coated metallically and then demetallized at least in some portions.

23. The security element according to claim 5, wherein the microflectors have a depth of 5 μm to 20 μm.

24. The security element according to claim 10, wherein the surface coating is metallic.

25. The method according to any one of claims 12 to 15, wherein the microreflectors are configured with a depth of 5 μm to 20 μm.

26. The method according to claim 21, wherein the surface coating is metallic.

27. The security element according to claim 8, wherein the metallic coating is Al, Ag, Au, Cu, Cr or an alloy containing said metals.

28. The method according to claim 19, wherein the metallic coating is Al, Ag, Au, Cu, Cr or an alloy containing said metals.

Date Reçue/Date Received 2020-10-08

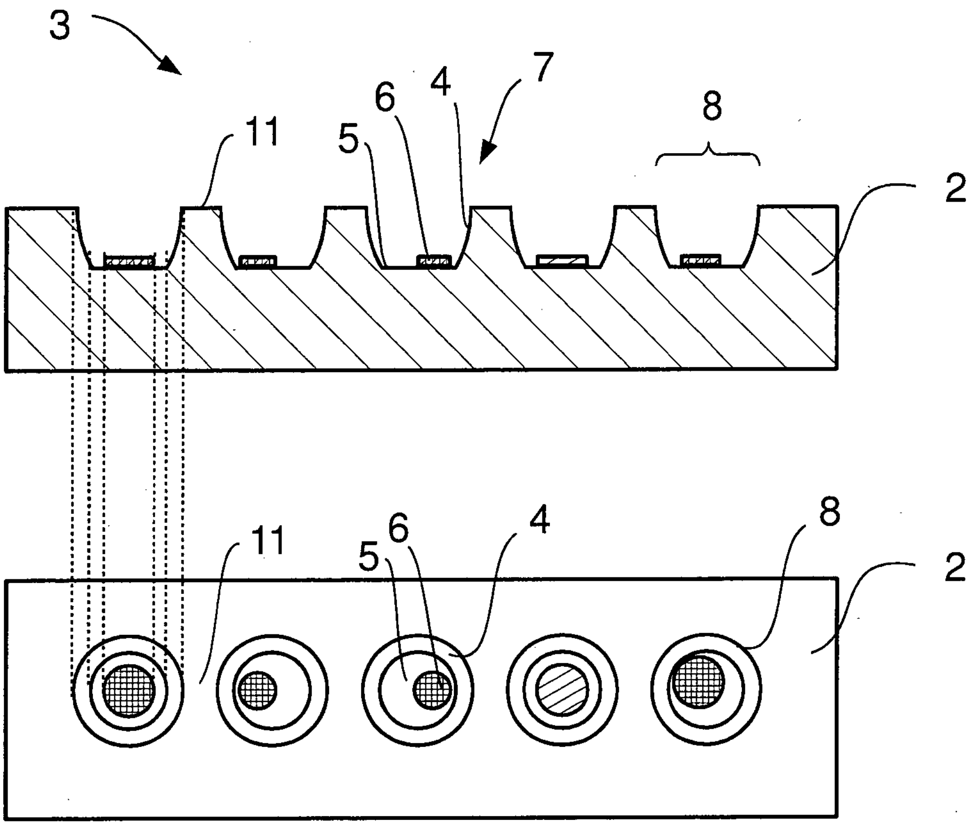


Fig. 1

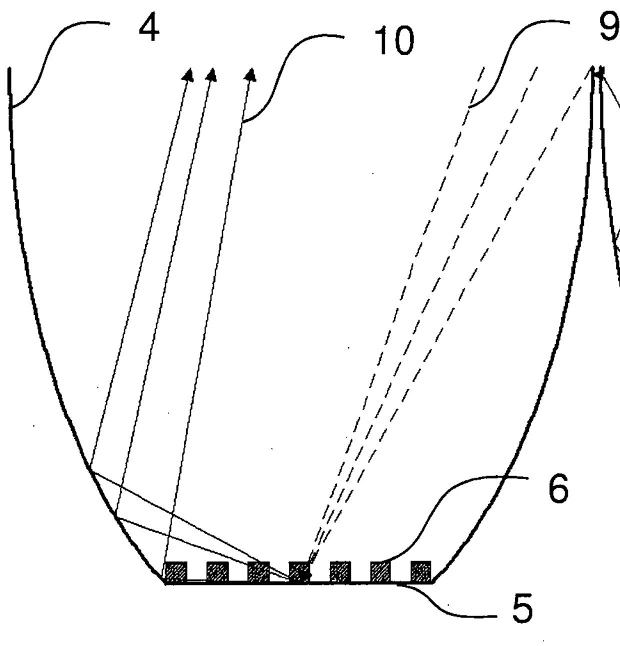


Fig. 2a

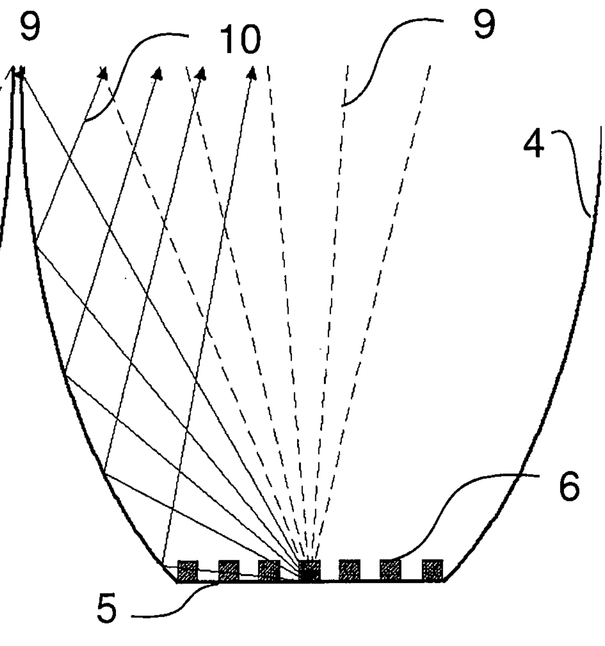


Fig. 2b

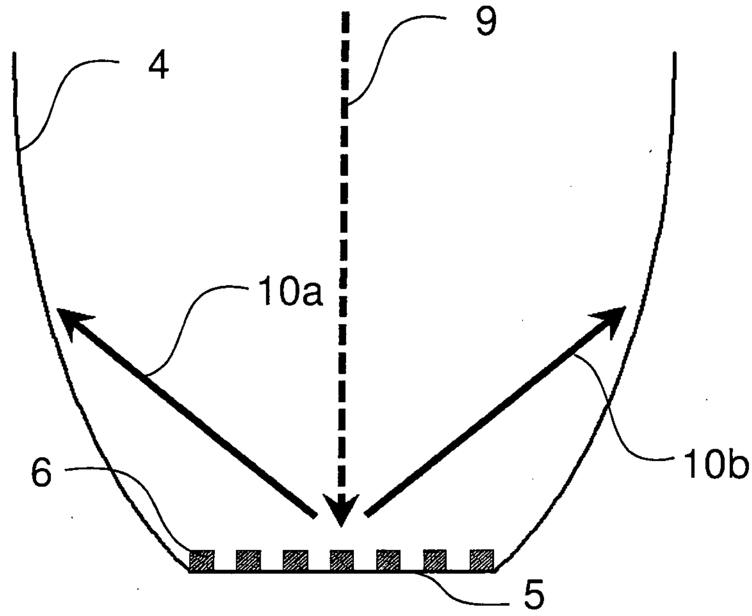


Fig. 3a

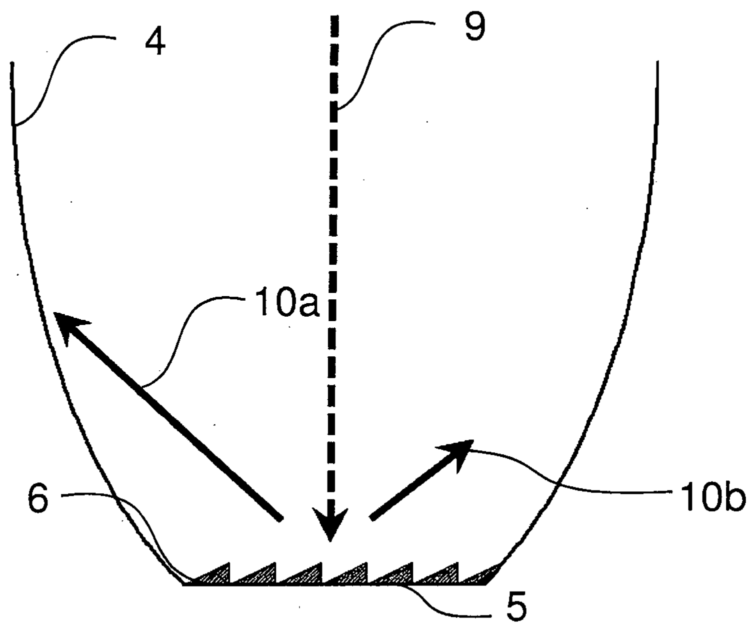


Fig. 3b

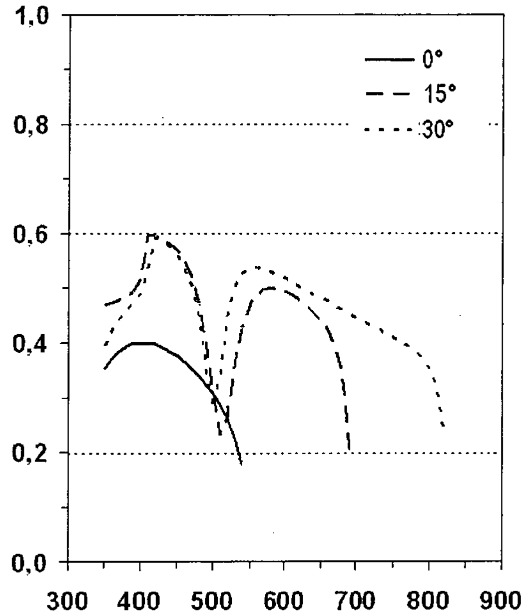


Fig. 4a

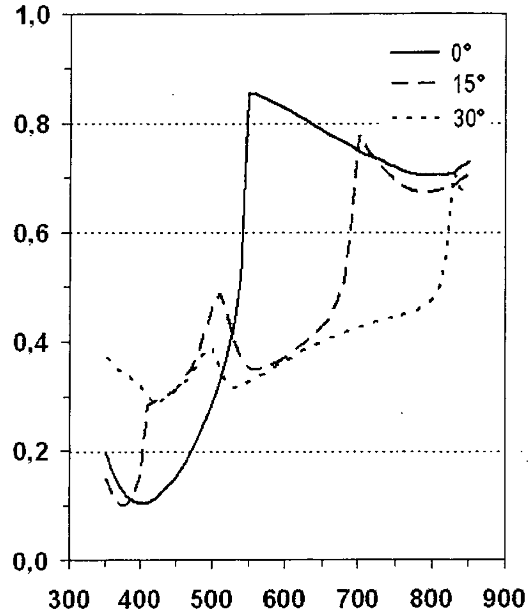


Fig. 4b

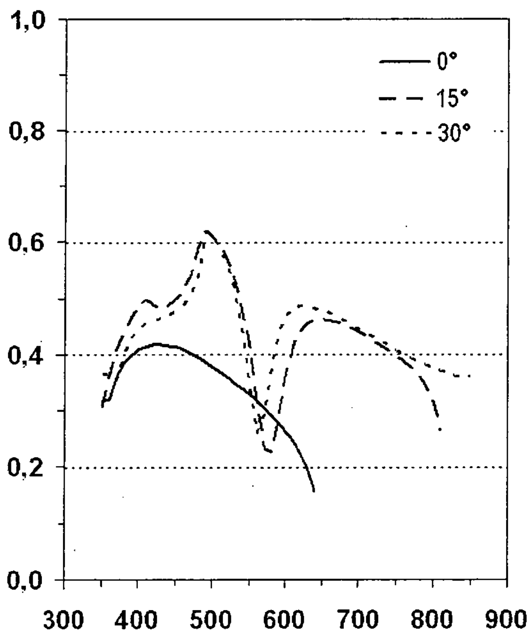


Fig. 5a

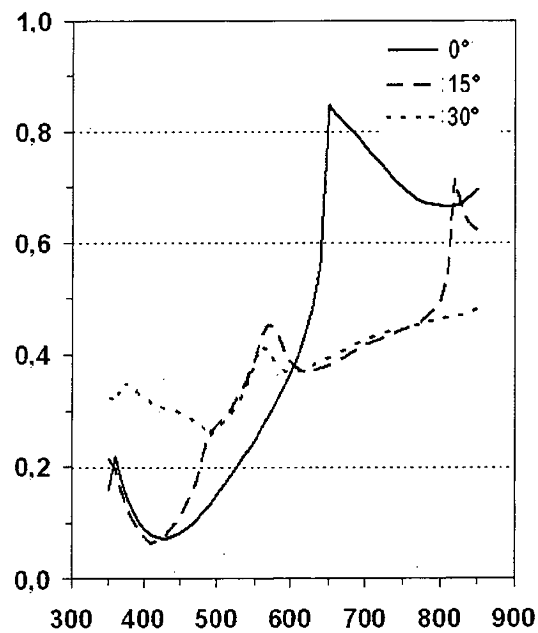


Fig. 5b

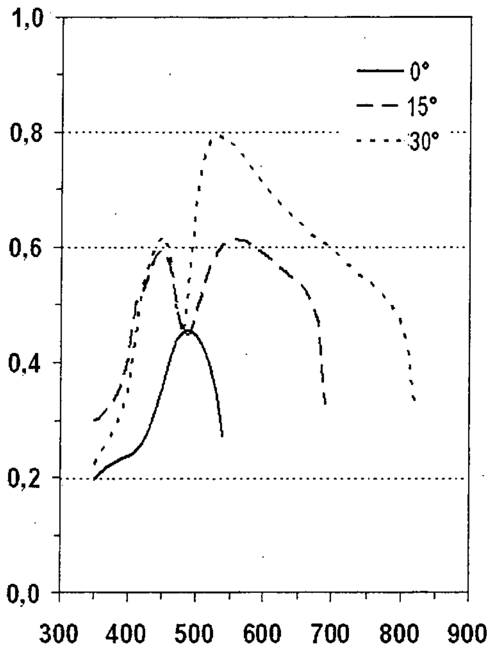


Fig. 6a

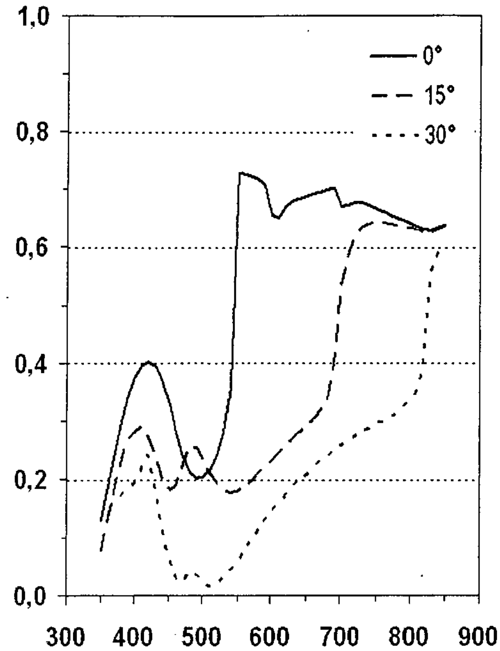


Fig. 6b

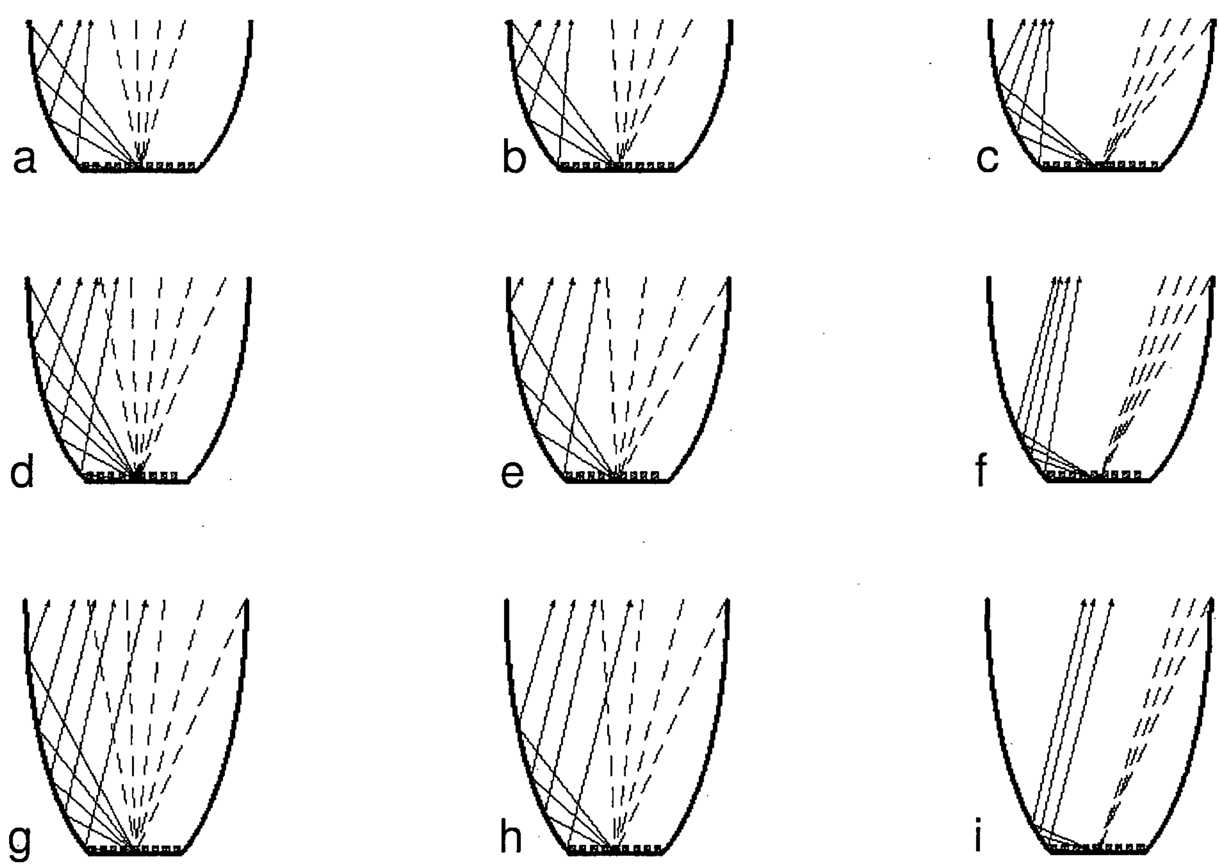


Fig. 7

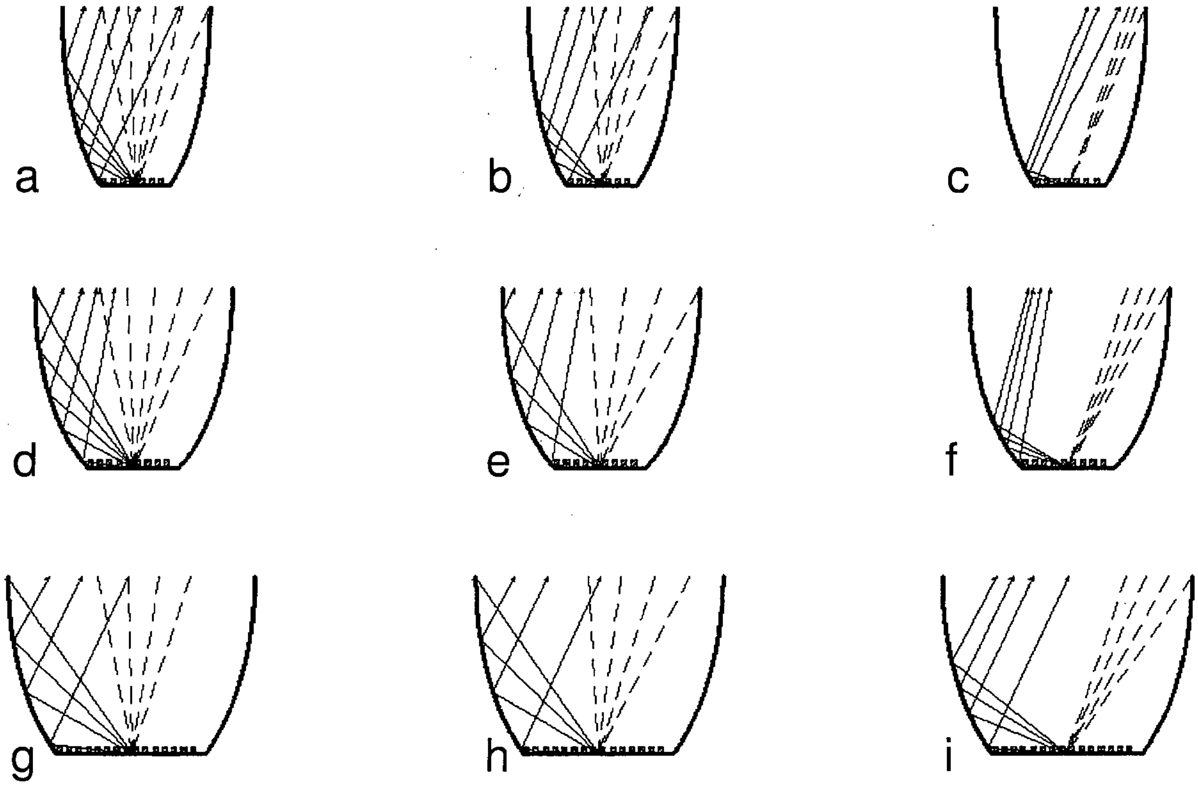


Fig. 8

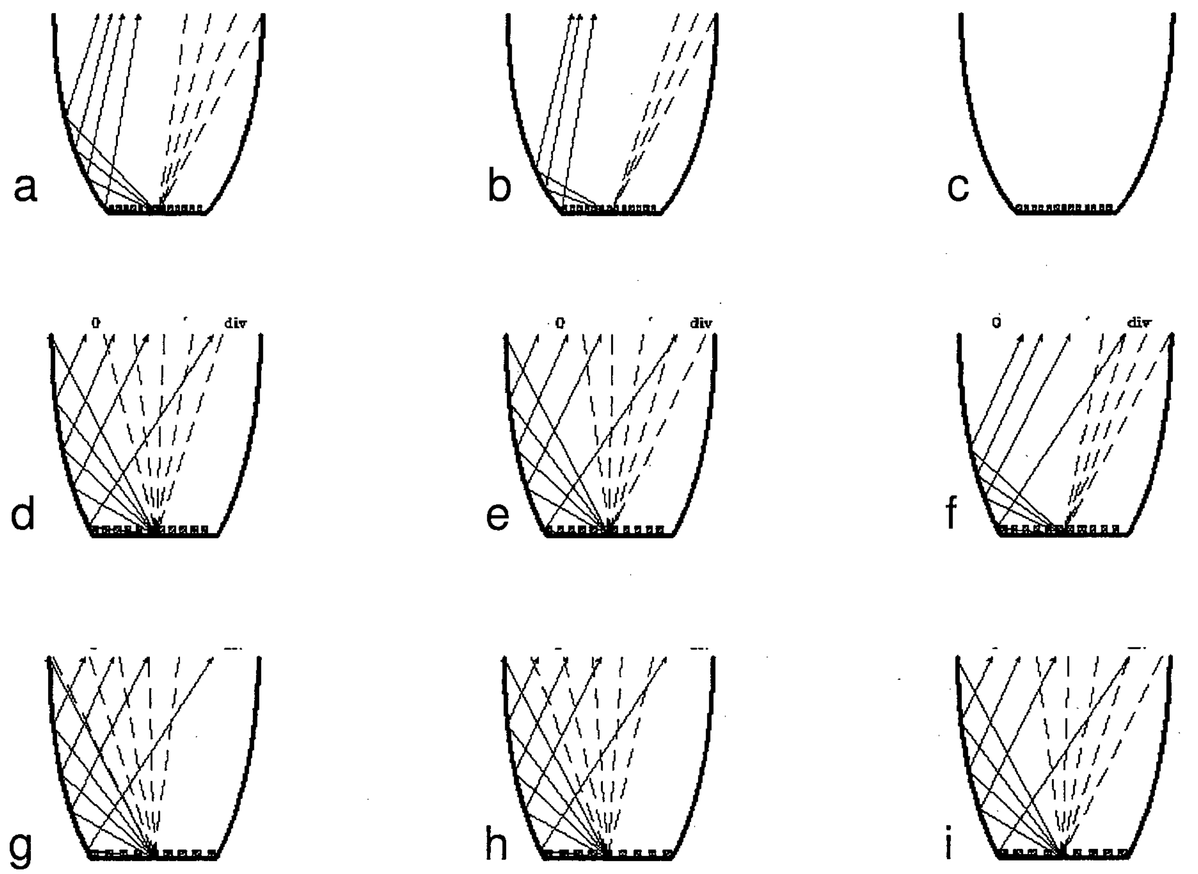


Fig. 9

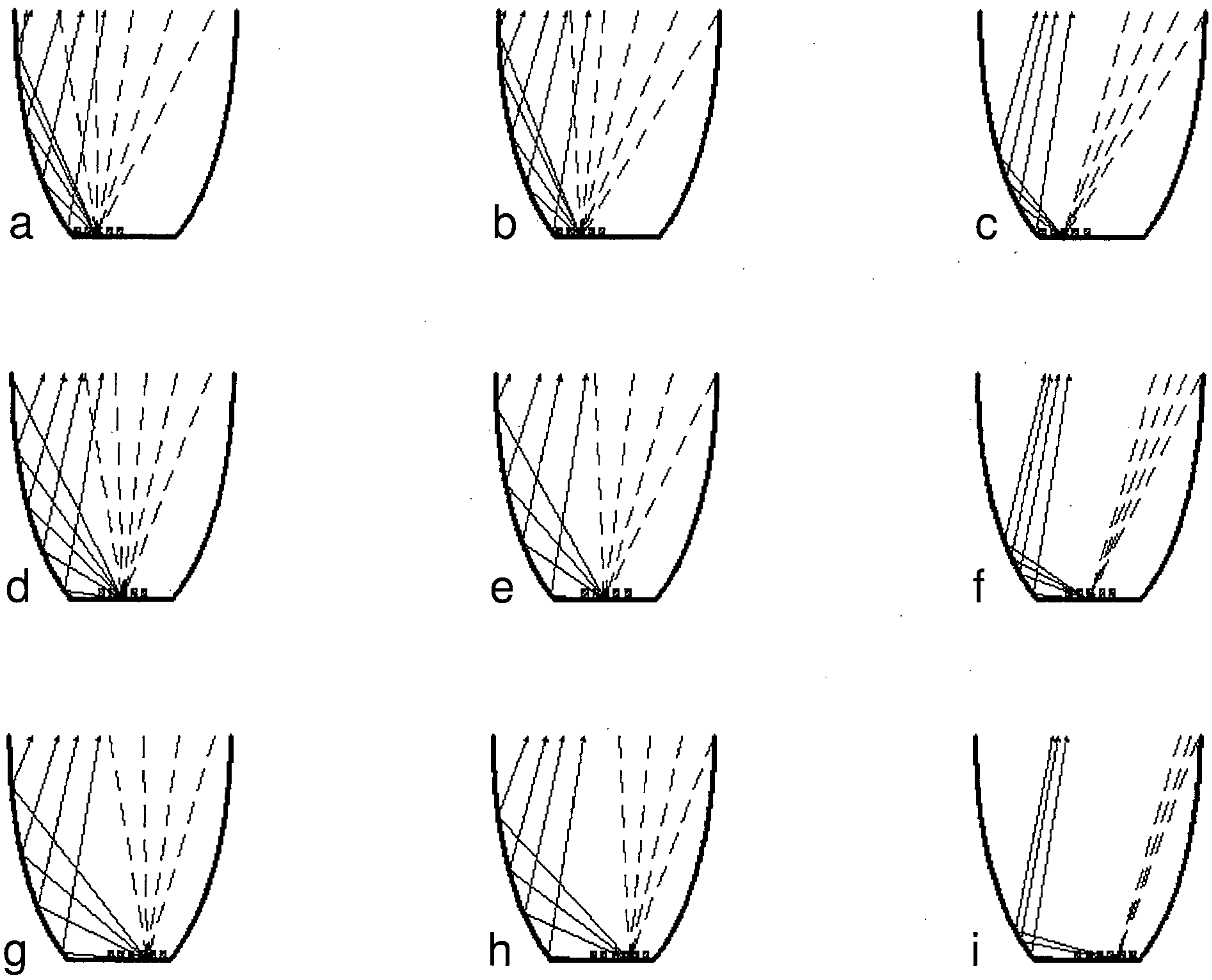


Fig. 10

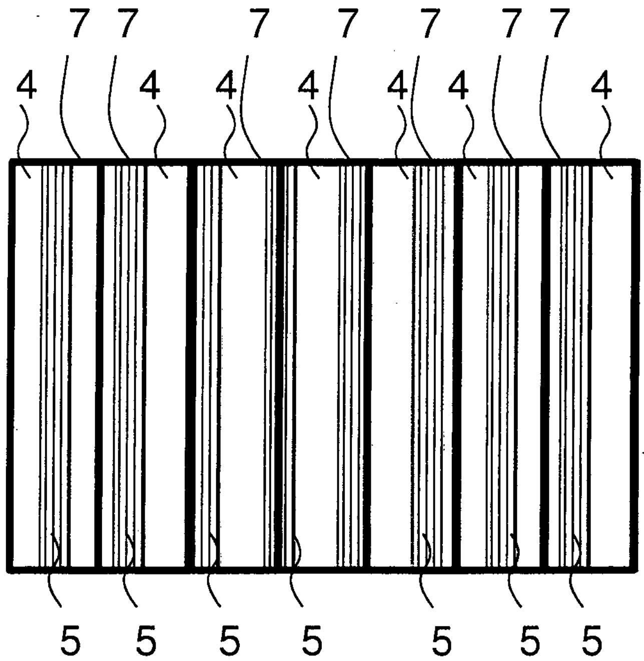


Fig. 11

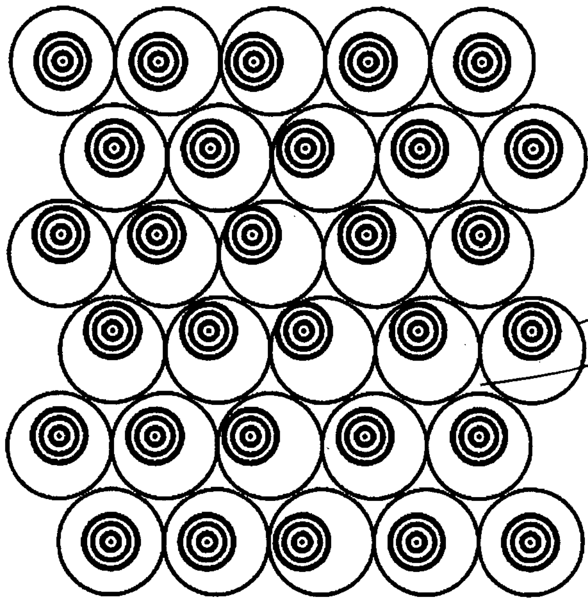


Fig. 12

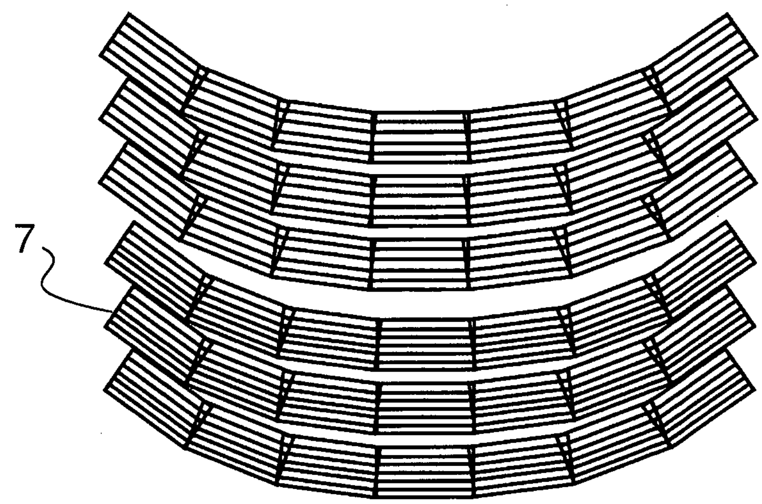


Fig. 13

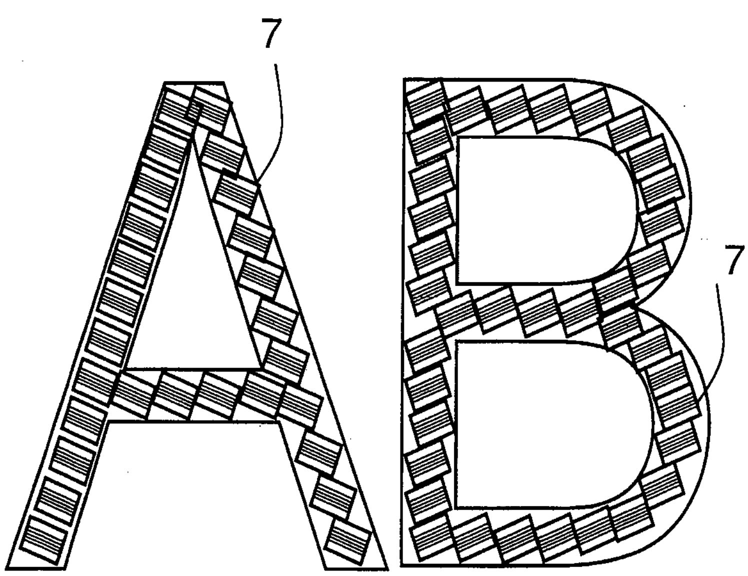


Fig. 14

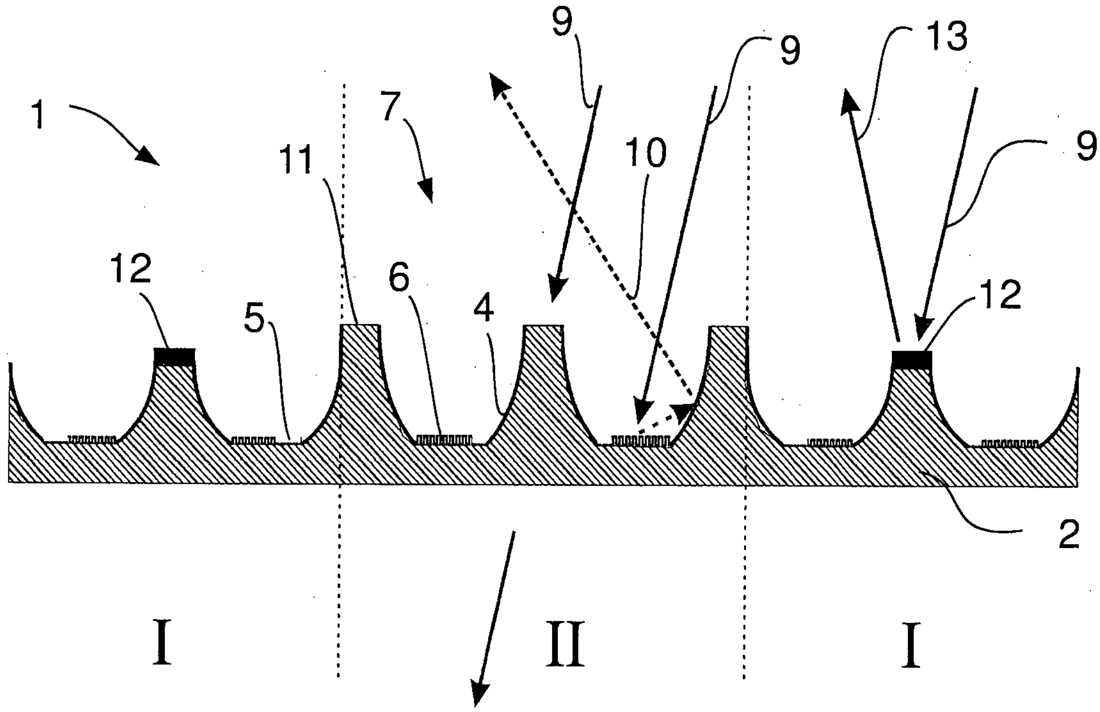


Fig. 15

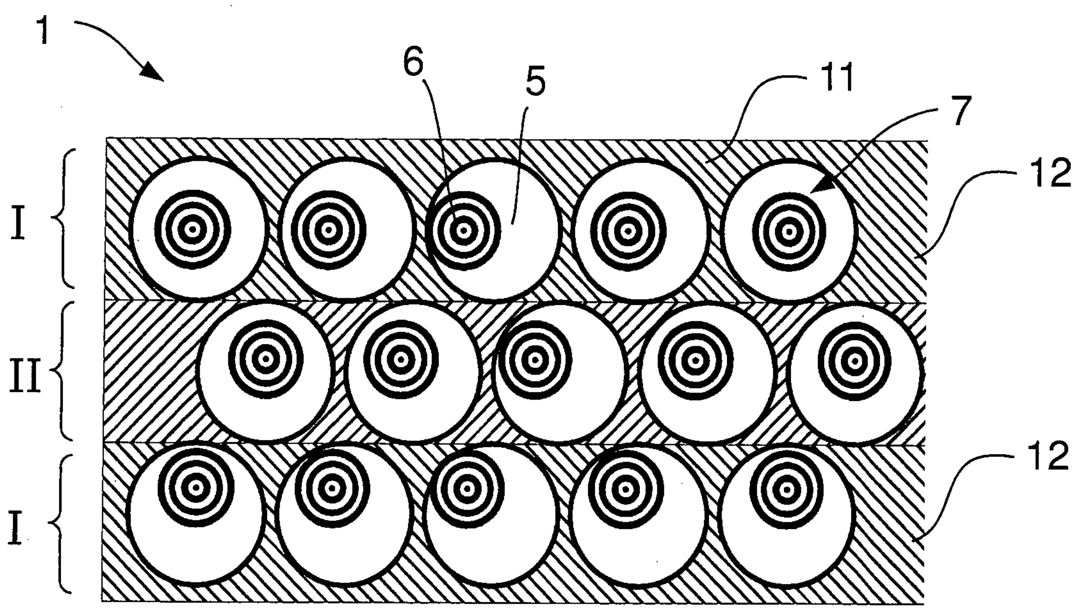
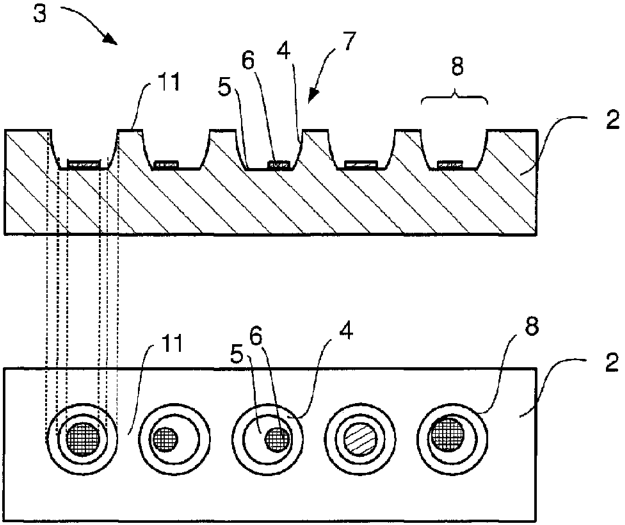


Fig. 16



3
7
11
5
6
4
8
2
11
5
6
4
8
2