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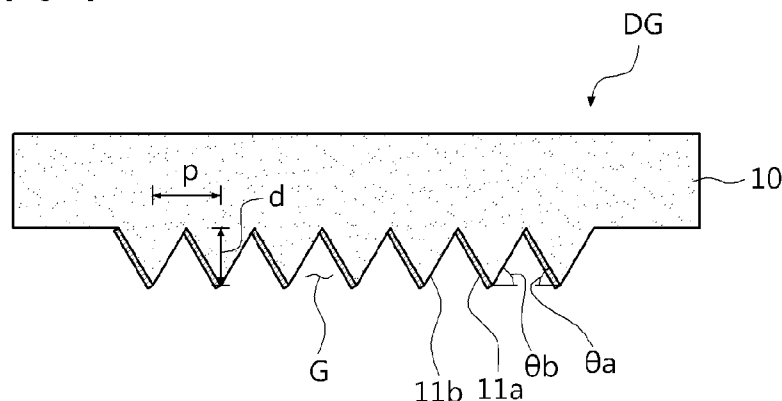
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(54) Title: TRANSMISSION DIFFRACTION DEVICE FOR HIGH DIFFRACTION ORDER AND METHOD OF FABRICATING THE SAME

[Fig. 1]



(57) Abstract: A transmission diffraction device having a high diffraction order and a method of fabricating the same are provided. The diffraction device includes a light transmissible body, and at least one V-shaped groove formed in the light transmissible body. The V-shaped groove includes reflection and refraction planes. This diffraction device produces high-order diffracted light. As the diffraction order of the diffracted light becomes higher, the resolving power of the diffraction device can be improved.

Description

Title of Invention: TRANSMISSION DIFFRACTION DEVICE FOR HIGH DIFFRACTION ORDER AND METHOD OF FAB- RICATING THE SAME

Technical Field

- [1] The present invention generally relates to an optical device, and more particularly to a diffraction device.

Background Art

- [2] As applied optical instrument industries such as optical communication industries continue to be developed, optical systems required by the industries show a tendency to be gradually made smaller in size and lighter in weight. In response to this tendency, refraction optical systems such as lenses and prisms are being replaced by diffraction optical systems such as planar diffraction lenses and diffraction gratings to meet sub-miniature and ultralight requirements.
- [3] The diffraction grating is an optical device that includes slits having a very narrow spacing and causes constructive and destructive interferences when light passes through to produce a diffracted light flux in a predetermined direction. In comparison with the prism of the refraction optical system, this diffraction grating has better optical dispersive power, and can be made smaller in size and lighter in weight.
- [4] However, in order to closely split the wavelengths of a light source such as a spectroscopy, it is necessary to further improve the resolving power of the diffraction grating.

Disclosure of Invention

Technical Problem

- [5] The present invention is directed to providing a diffraction device resolving power is improved and a method of fabricating the same.
- [6] The present invention is not limited to the above-mentioned technical problem, and other problems that are not mentioned above would be clearly understood by those skilled in the art based on the following disclosure.

Solution to Problem

- [7] In order to accomplish the technical problem, one aspect of the present invention provides a diffraction device. The diffraction device includes a light transmissible body, and at least one V-shaped groove formed in the light transmissible body. The V-shaped groove includes reflection and refraction planes.
- [8] The reflection plane may be a reflection layer formed on one sidewall of the V-

shaped groove. The reflection layer may be an aluminum layer, a gold layer, a silver layer, or a composite layer thereof.

[9] The reflection plane may have an angle ranging from about 40° to about 70°, particularly from about 50° to about 60°, with respect to an open plane of the V-shaped groove.

[10] The light transmissible body may be formed of glass or light transmissible resin.

[11] Another aspect of the present invention provides a method of fabricating a diffraction device. The method includes preparing a light transmissible body having at least one V-shaped groove. A reflection layer is selectively formed on one sidewall of the V-shaped groove.

[12] The preparing of the light transmissible body having at least one V-shaped groove may include preparing a template substrate having at least one template groove, coating light transmissible resin on the template substrate, and pressurizing the coated light transmissible resin. The template substrate may be prepared by forming a mask pattern on a silicon substrate having a (100) plane, and by selectively etching a (111) plane of the silicon substrate using the mask pattern as an etch mask.

[13] The selectively etching of the (111) plane of the silicon substrate may be performed using ethylenediamine pyrocatechol (EDP) water, tetramethyl ammonium hydroxide (TMAH), or potassium hydroxide (KOH).

Advantageous Effects of Invention

[14] According to the present invention, a diffraction device having V-shaped grooves, each of which has a reflection plane on one of sidewalls thereof and a refraction plane on the other sidewall, can produce high-order diffracted light. As the diffraction order of the diffracted light becomes higher, the resolving power of the diffraction device can be improved.

Brief Description of Drawings

[15] FIG. 1 is a cross-sectional view of a diffraction device according to an exemplary embodiment of the present invention.

[16] FIGS. 2 and 3 are cross-sectional views illustrating a diffraction order of light transmitted through a diffraction device according to an exemplary embodiment of the present invention.

[17] FIG. 4 is a cross-sectional view illustrating a diffraction order of light transmitted through a conventional diffraction device.

[18] FIGS. 5 through 11 are cross-sectional views illustrating a method of fabricating a diffraction device according to an exemplary embodiment of the present invention.

[19] FIG. 12 is a scanning electron microscope (SEM) photograph of a surface of a silicon substrate, which has template grooves and is fabricated according to Example 1.

[20] FIG. 13 is a SEM photograph of a cross section of a diffraction device fabricated according to Example 1.

[21] FIG. 14 is a graph illustrating diffraction efficiency of incident light in the visible light range of the diffraction device fabricated according to Example 1.

[22] FIG. 15 is a graph illustrating diffraction efficiency according to the diffraction order of incident light having a wavelength of 406 nm.

[23] FIG. 16 is a graph illustrating diffraction efficiency of incident light in the visible light range of a diffraction device fabricated according to Example 2.

[24] FIGS. 17 and 18 are photographs of diffracted light obtained when light having a wavelength of 406 nm is incident on the diffraction device according to Example 1.

Mode for the Invention

[25] Reference will now be made in detail to some exemplary embodiments, examples of which are illustrated in the accompanying drawings. However, the present invention is not limited to one exemplary embodiment described below, but may be embodied in a variety of forms. In the drawings, if it is mentioned that a layer is positioned "on" a different layer or a substrate, the layer may be formed directly on the different layer or the substrate, or another layer may be interposed therebetween.

[26] The terminology used herein is for the purpose of describing particular exemplary embodiments only and is not intended to be limiting of example embodiments. As used herein, the singular forms are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises," "comprising," "includes" and/or "including," when used herein, specify the presence of stated features, integers, steps, operations, elements and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components and/or combinations thereof.

[27] Unless specifically defined, all the terms used herein including technical or scientific terms have the same meaning as terms generally understood by those skilled in the art. Terms defined in a general dictionary should be understood so as to have the same meanings as contextual meanings of the related art. Unless definitely defined in the present invention, the terms are not interpreted as ideal or excessively formal meanings.

[28] FIG. 1 is a cross-sectional view of a diffraction device according to an exemplary embodiment of the present invention.

[29] Referring to FIG. 1, the diffraction device DG includes V-shaped grooves G, which are diffraction gratings, in one surface of a light transmissible body 10. The light transmissible body 10 may be a glass substrate or a light transmissible resin substrate. An

example of the light transmissible resin substrate may include a polymethylmethacrylate (PMMA) substrate or a polycarbonate substrate.

- [30] The V-shaped grooves G are arranged with a depth d and a period p. Each V-shaped groove G is configured so that opposite inclined sidewalls thereof join at one point. One of the opposite sidewalls functions as a reflection plane 11a, and the other functions as a refraction plane 11b. The reflection plane 11a may have a structure in which a reflection layer is formed on the sidewall. The reflection layer may be a metal layer such as a gold layer, a silver layer, an aluminum layer or a composite layer thereof. Particularly, the reflection layer may be an aluminum layer. In order to generate high-order diffracted light, a first angle θ_a between the reflection plane 11a and an open plane of the V-shaped groove G may range from 40° to 70°, and particularly from 50° to 60°. An angle θ_b between the refraction plane 11b and the open plane of the V-shaped groove G may be equal to or different from the first angle θ_a .
- [31] FIGS. 2 and 3 are cross-sectional views illustrating a diffraction order of light transmitted through a diffraction device according to an exemplary embodiment of the present invention.
- [32] Referring to FIGS. 2 and 3, diffracted light L_{d2} of light L_{i2} that is incident on the reflection plane 11a of each V-shaped groove G has a higher diffraction order, compared to diffracted light L_{d1} of light L_{i1} that is incident on the refraction plane 11b of each V-shaped groove G. This may result from the fact that the reflection plane 11a reflects the light L_{i2} to vary an incident angle on the refraction plane 11b.
- [33] For example, the incident light L_{i1} having a wavelength of 406 nm is diffracted to cause constructive interference to meet -4 diffraction order when a path difference between light L_{d1} transmitted through one refraction plane 11b and neighboring light L_{d1} transmitted through the neighboring refraction plane 11b is four times the wavelength. Meanwhile, the incident light L_{i2} having a wavelength of 406 nm is diffracted to cause constructive interference to meet -10 diffraction order when a path difference between light L_{d2} which is transmitted through the refraction plane 11b after being reflected from the reflection plane 11a and neighboring light L_{d2} which is transmitted through the neighboring refraction plane 11b after being reflected from the neighboring reflection plane 11a is ten times the wavelength.
- [34] The diffraction device has a resolving power that increases in proportion to the number of diffraction gratings and the diffraction order as in the following formula. Thus, in the case of the same period and number of diffraction gratings, the diffraction device having a higher diffraction order has a higher resolving power.
- [35] <Formula 1>
- [36] *Resolving power = mN*

- [37] In Formula 1, m is the diffraction order, and N is the number of diffraction gratings.
- [38] FIG. 4 is a cross-sectional view illustrating a diffraction order of light transmitted through a conventional diffraction device.
- [39] Referring to FIG. 4, the diffraction device DG includes V-shaped grooves G, which constitute a grating pattern, in one surface of a light transmissible body 1. Each V-shaped groove G has opposite sidewalls, which are refraction planes 1b. Lights L_{i3} and $L_{i3'}$ incident on the opposite refraction planes 1b are capable of producing diffracted lights L_{d3} and $L_{d3'}$ having positive and negative orders, but they have difficulty in producing light having a high diffraction order.
- [40] FIGS. 5 through 11 are cross-sectional views illustrating a method of fabricating a diffraction device according to an exemplary embodiment of the present invention.
- [41] Referring to FIG. 5, a template substrate 100 is prepared. The template substrate 100 may be a silicon substrate, but is not limited to this substrate. A hard mask layer 101 may be formed on the template substrate 100. The hard mask layer 101 may be a silicon oxide layer. When the template substrate 100 is a silicon substrate, the silicon oxide layer may be formed by thermal oxidation of the template substrate 100.
- [42] Referring to FIG. 6, a photoresist pattern 102 may be formed on the hard mask layer 101.
- [43] Referring to FIG. 7, the hard mask layer 101 is etched using the photoresist pattern 102 as a mask, thereby forming a hard mask pattern 101a.
- [44] Referring to FIG. 8, the photoresist pattern 102 is removed, and then the template substrate 100 is etched using the hard mask pattern 101a as a mask, thereby forming template grooves 100a within the template substrate 100. Triangular convexes may be defined by the template grooves 100a.
- [45] The template grooves 100a may be formed by anisotropic etching, for instance anisotropic wet etching, anisotropic dry etching, high-speed atomic beam etching, reactive ion etching or laser etching.
- [46] If the template substrate 100 is a silicon substrate having a (100) plane as a upper plane, the template substrate 100 is etched using a solution showing an anisotropic etching of the (100) plane to a (111) plane, for example, ethylenediamine pyrocatechol (EDP) water, tetramethyl ammonium hydroxide (TMAH), or potassium hydroxide (KOH). As a result, the (111) plane of the template substrate 100 can be exposed to produce the template grooves 100a. The sidewalls of each template groove 100a may have an angle of about 54.7 with respect to a open plane of each template groove 100a.
- [47] Referring to FIG. 9, the hard mask pattern 101a is removed to expose the template substrate 100.
- [48] Referring to FIG. 10, the template substrate 100 having the template grooves 100a is covered with an optical resin, and then is pressurized, so that a light transmissible body

10, a molded optical resin layer, is formed. Thus, the light transmissible body 10 may be provided with V-shaped grooves G defined by the triangular convexes 100b. The optical resin may include polymethylmetacrylate (PMMA) or polycarbonate resin.

[49] In this manner, the light transmissible body 10 may be replicated using a hot embossing technique.

[50] Referring to FIG. 11, a reflection layer 11a is selectively formed on only one of the sidewalls of each V-shaped groove G. To this end, a mask pattern 12 may be formed on regions other than a region where the V-shaped grooves G of the light transmissible body 10 are formed.

[51] The reflection layer 11a may be formed by sputtering or thermal deposition using a characteristic of a deposited material beam B to travel linearly.

[52] Hereinafter, examples are given in order to help understanding of the present invention. However, the following examples are merely intended to help understanding of the present invention, and thus the present invention is not limited to these examples.

[53]

[54] **Example 1**

[55] A silicon oxide layer was formed by thermally oxidizing a silicon substrate having a (100) plane. A photoresist pattern was formed on the silicon oxide layer, and then the silicon oxide layer was etched using the photoresist pattern as a mask, thereby forming a hard mask pattern. The photoresist pattern was removed, and then the silicon substrate was etched with a TMAH solution using the hard mask pattern as a mask, thereby forming template grooves exposing a (111) plane within the silicon substrate. The template substrate 100 having the template grooves was covered with PMMA and was pressurized, thereby forming a diffraction device having V-shaped grooves. The diffraction device was rotated such that one of sidewalls of each V-shaped groove thereof was perpendicular to an aluminum deposition source, and then an aluminum thin layer was selectively formed on the sidewall of each V-shaped groove.

[56]

[57] **Example 2**

[58] A diffraction device was fabricated using the same method as in Example 1 without forming the aluminum thin layer on the sidewall of each V-shaped groove.

[59]

[60] FIG. 12 is a scanning electron microscope (SEM) photograph of a surface of the silicon substrate, which has the template grooves and is fabricated according to Example 1, and FIG. 13 is a SEM photograph of a cross section of the diffraction device fabricated according to Example 1.

[61] Referring to FIGS. 12 and 13, it can be seen that the period of the template grooves is

3 μm , and that the depth of each V-shaped groove is 2.133 μm . Both the period of the template grooves and the depth of each V-shaped groove in Example 2 are substantially the same as those in Example 1.

[62] FIG. 14 is a graph illustrating diffraction efficiency of incident light in the visible light range of the diffraction device fabricated according to Example 1, and FIG. 15 is a graph illustrating diffraction efficiency according to the diffraction order of incident light having a wavelength of 406 nm. FIG. 16 is a graph illustrating diffraction efficiency of incident light in the visible light range of the diffraction device fabricated according to Example 2.

[63] Referring to FIGS. 14, 15 and 16, it can be seen that, in the case of the diffraction device having the V-shaped grooves with no reflection plane (Example 2 and FIG. 16), the diffracted light having ± 4 diffraction orders has high diffraction efficiency within a wavelength range from 400 nm to 450 nm, while the diffracted light having ± 3 diffraction orders has high diffraction efficiency within a wavelength range from 500 nm to 600 nm.

[64] In contrast, it can be seen that, in the case of the diffraction device having the V-shaped grooves with reflection planes (Example 1 and FIGS. 14 and 15), the diffracted light having -4 and -10 diffraction orders has high diffraction efficiency within a wavelength range from 400 nm to 450 nm, particularly at a wavelength of 406 nm. Further, it can be seen that the diffracted light having high diffraction orders such as -6 through -10 diffraction orders is produced within a wavelength range from 400 nm to 700 nm.

[65] From the foregoing, it can be seen that the diffraction device of the present invention, i.e. the diffraction device having the V-shaped grooves, each of which has the reflection plane on one of the sidewalls thereof and the refraction plane on the other sidewall, can produce the high-order diffracted light within the visible light range. As described with reference to Formula 1, the higher the diffraction order of the diffracted light, the higher the resolving power of the diffraction device.

[66] FIGS. 17 and 18 are photographs of diffracted light obtained when light having a wavelength of 406 nm is incident on the diffraction device according to Example 1.

[67] Referring to FIGS. 17 and 18, it can be seen that the diffracted light having 0 through -6, and -10 diffraction orders can be obtained. Further, the diffracted light having -4 and -10 diffraction orders has efficiencies of 33.1% and 25.5%, respectively.

[68] While the exemplary embodiments of the present invention have been described with reference to the accompanying drawings, it will be apparent to those skilled in the art that various modifications and variations can be made in the present invention without departing from the scope of the invention. Thus, it is intended that any future modifications of the embodiments of the present invention will come within the scope of the

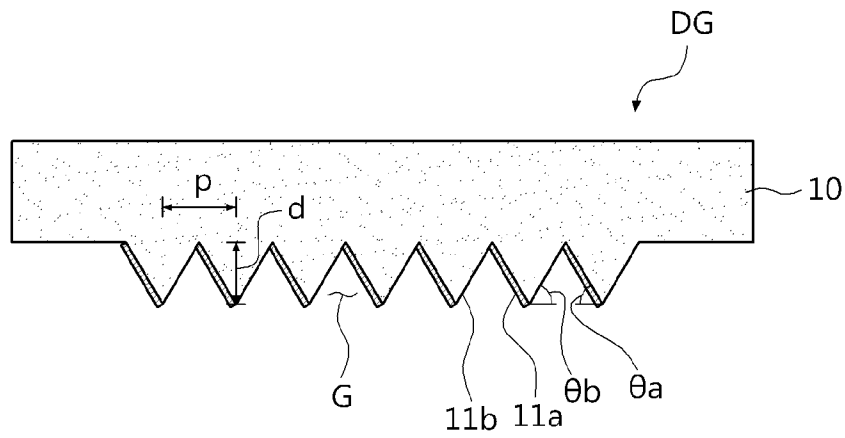
appended claims and their equivalents.

Claims

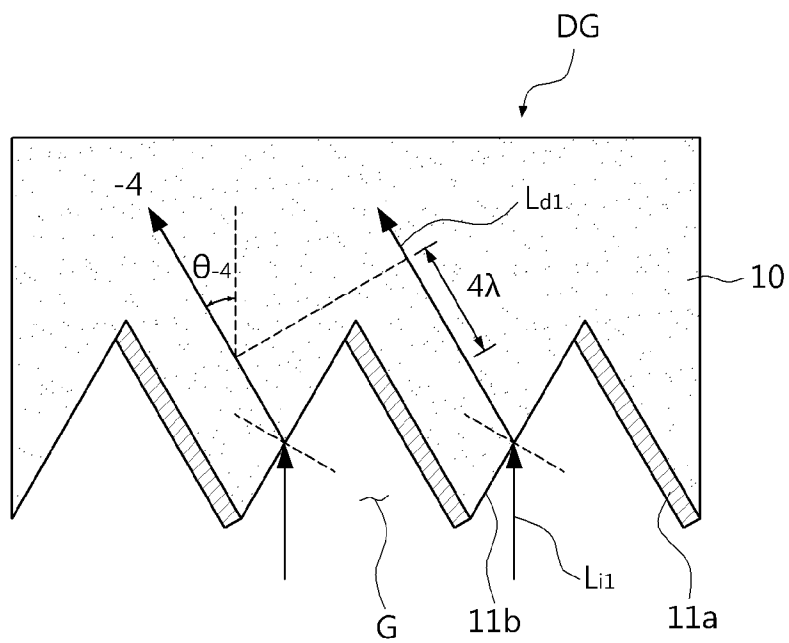
- [Claim 1] A diffraction device comprising:
a light transmissible body; and
at least one V-shaped groove formed in the light transmissible body and
having reflection and refraction planes.
- [Claim 2] The diffraction device according to claim 1, wherein the reflection
plane is a reflection layer formed on one sidewall of the V-shaped
groove.
- [Claim 3] The diffraction device according to claim 2, wherein the reflection
layer is an aluminum layer, a gold layer, a silver layer, or a composite
layer thereof.
- [Claim 4] The diffraction device according to claim 1, wherein the reflection
plane has an angle ranging from about 40° to about 70° with respect to
an open plane of the V-shaped groove.
- [Claim 5] The diffraction device according to claim 4, wherein the reflection
plane has an angle ranging from about 50° to about 60° with respect to
an openplane of the V-shaped groove.
- [Claim 6] The diffraction device according to claim 1, wherein the light trans-
missible body is formed of glass or light transmissible resin.
- [Claim 7] A method of fabricating a diffraction device, comprising:
preparing a light transmissible body having at least one V-shaped
groove; and
selectively forming a reflection layer on one sidewall of the V-shaped
groove.
- [Claim 8] The method according to claim 7, wherein the preparing of the light
transmissible body having at least one V-shaped groove includes:
preparing a template substrate having at least one template groove;
coating light transmissible resin on the template substrate; and
pressurizing the coated light transmissible resin.
- [Claim 9] The method according to claim 8, wherein the preparing of the template
substrate includes:
forming a mask pattern on a silicon substrate having a (100) plane; and
selectively etching a (111) plane of the silicon substrate using the mask
pattern as an etch mask.
- [Claim 10] The method according to claim 9, wherein the selectively etching of the
(111) plane of the silicon substrate is performed using ethylenediamine
pyrocatechol (EDP) water, tetramethyl ammonium hydroxide (TMAH),

or potassium hydroxide (KOH).

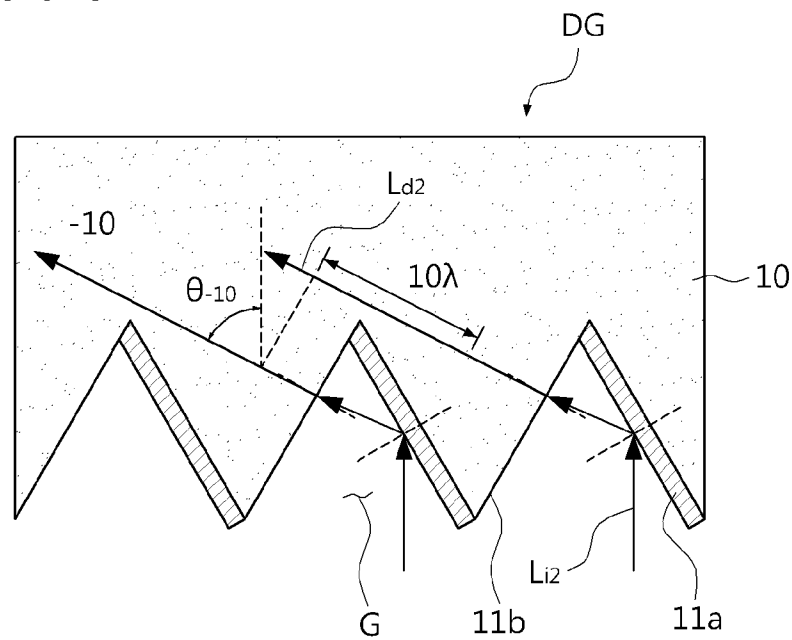
[Fig. 1]



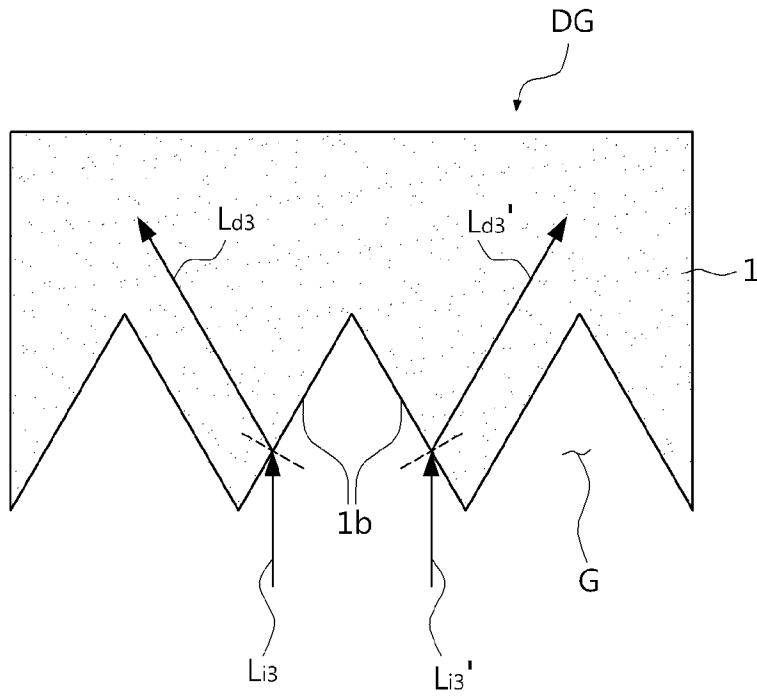
[Fig. 2]



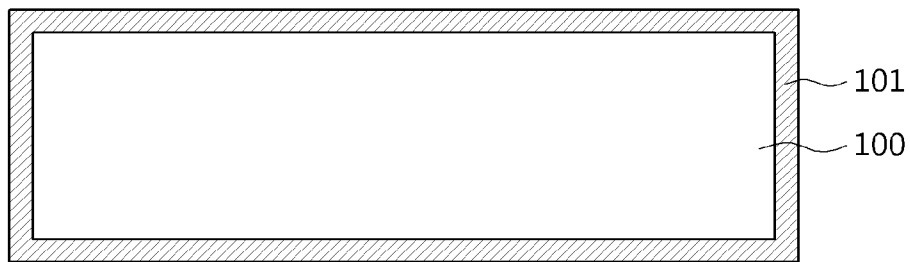
[Fig. 3]



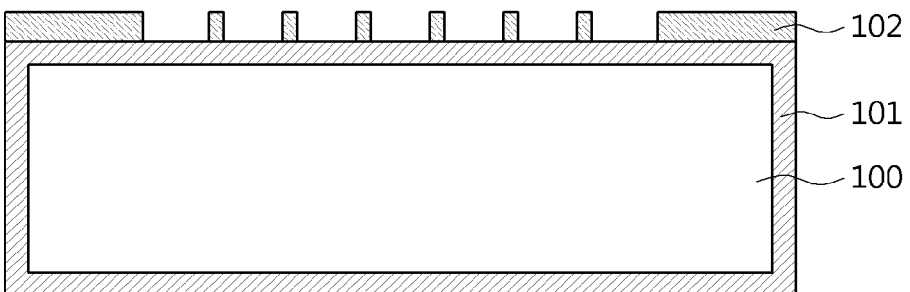
[Fig. 4]



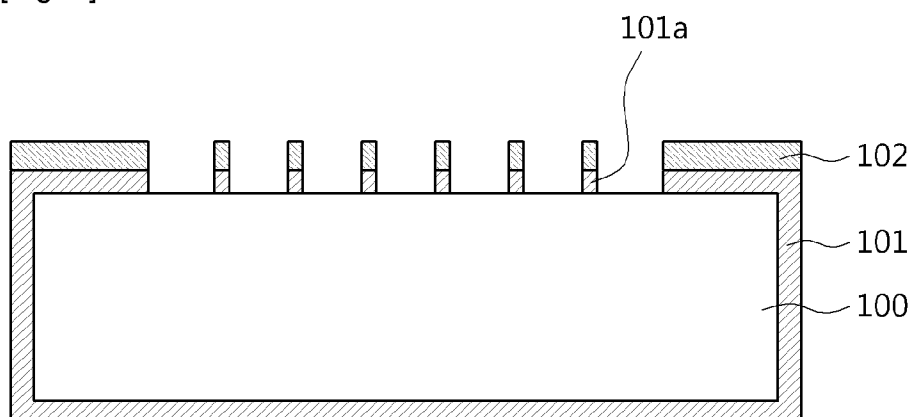
[Fig. 5]



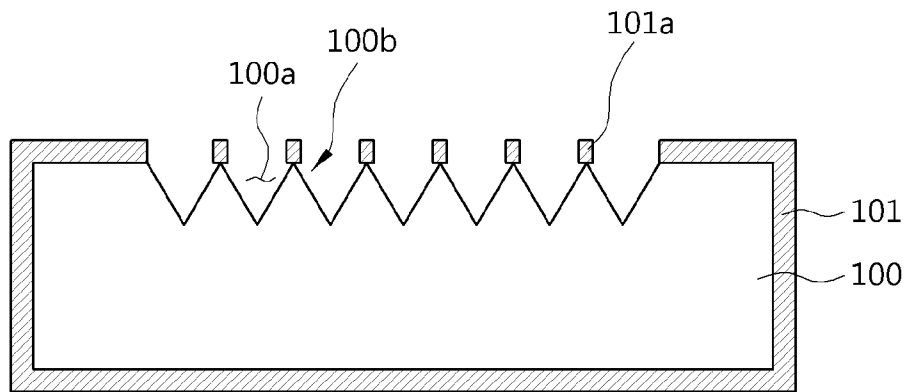
[Fig. 6]



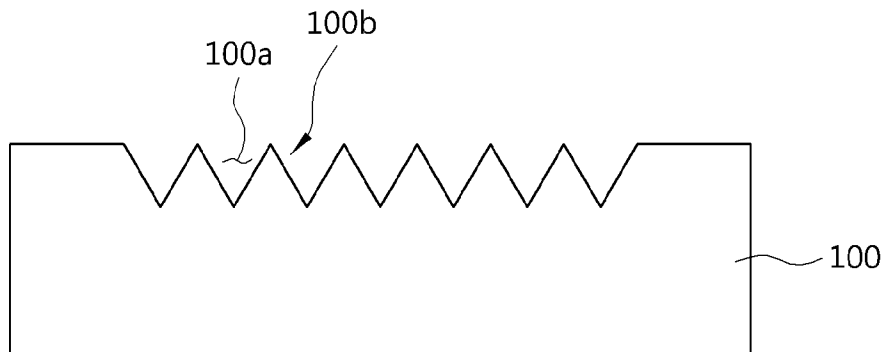
[Fig. 7]



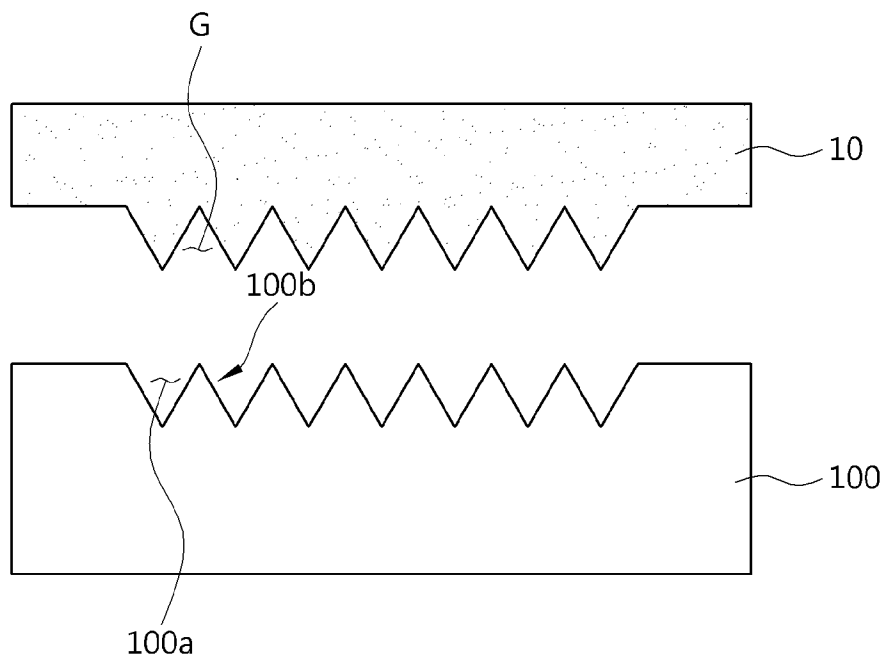
[Fig. 8]



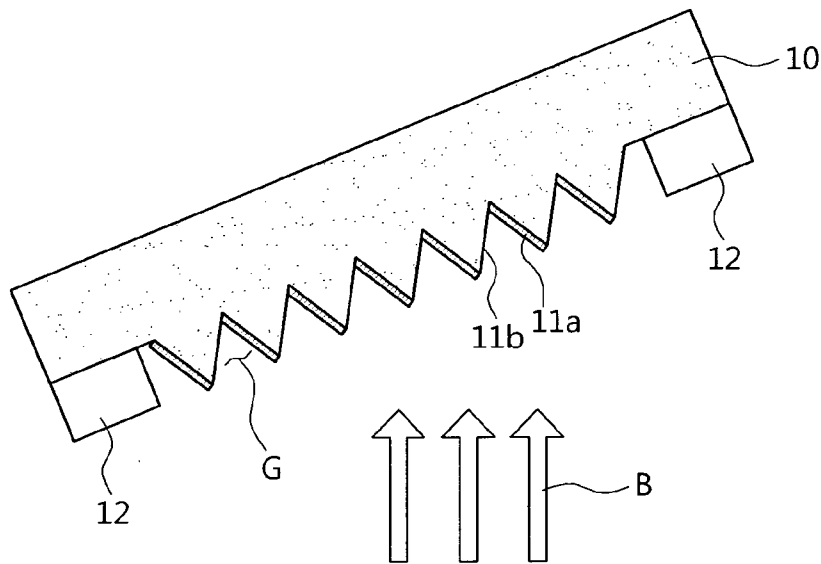
[Fig. 9]



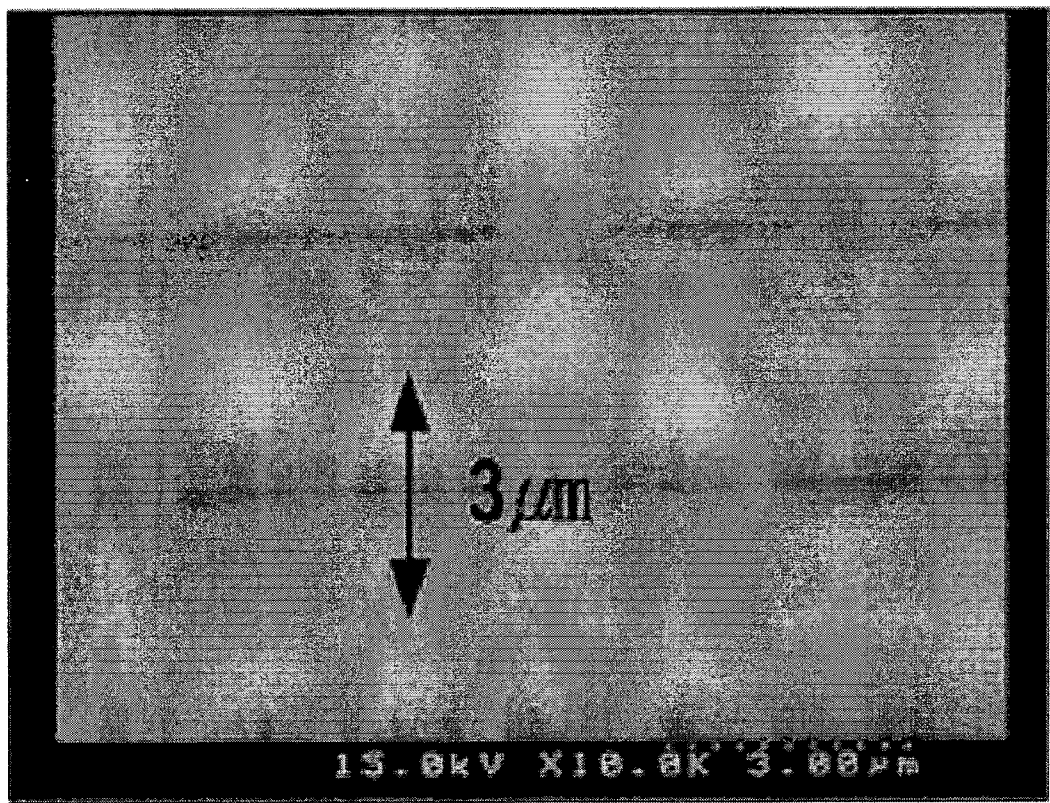
[Fig. 10]



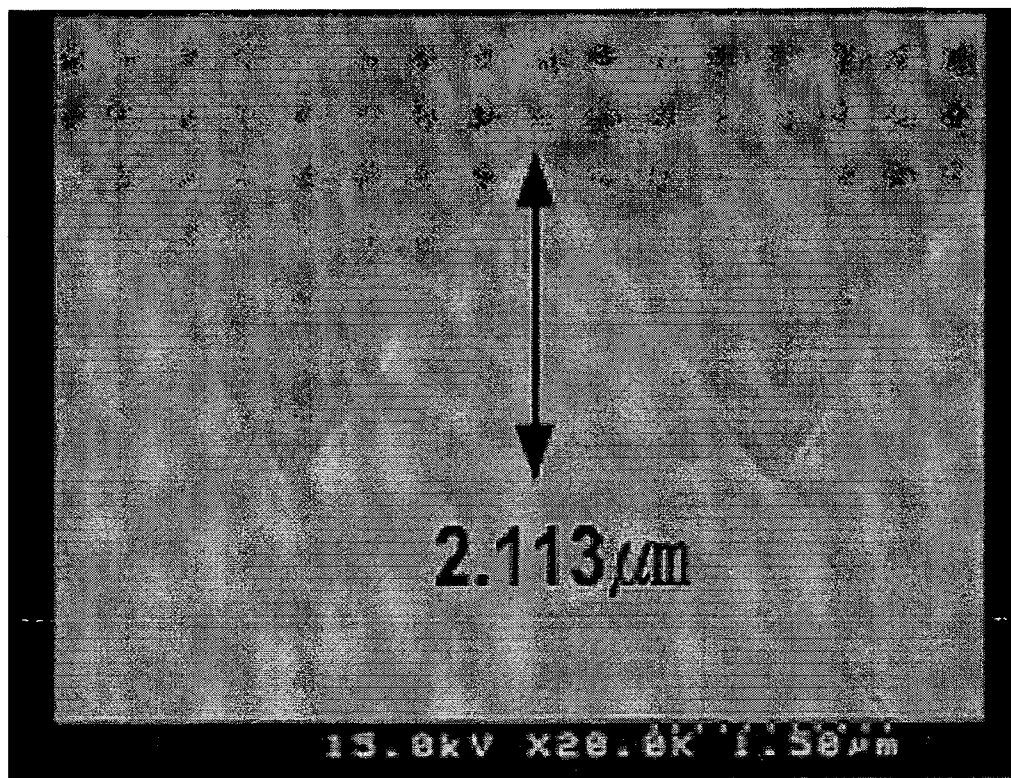
[Fig. 11]



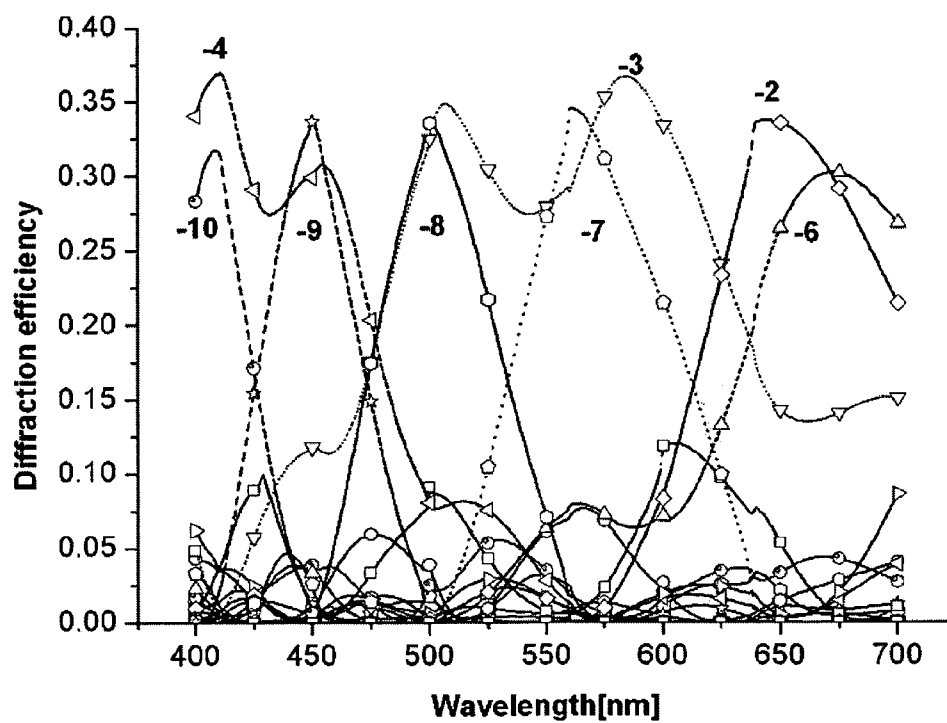
[Fig. 12]



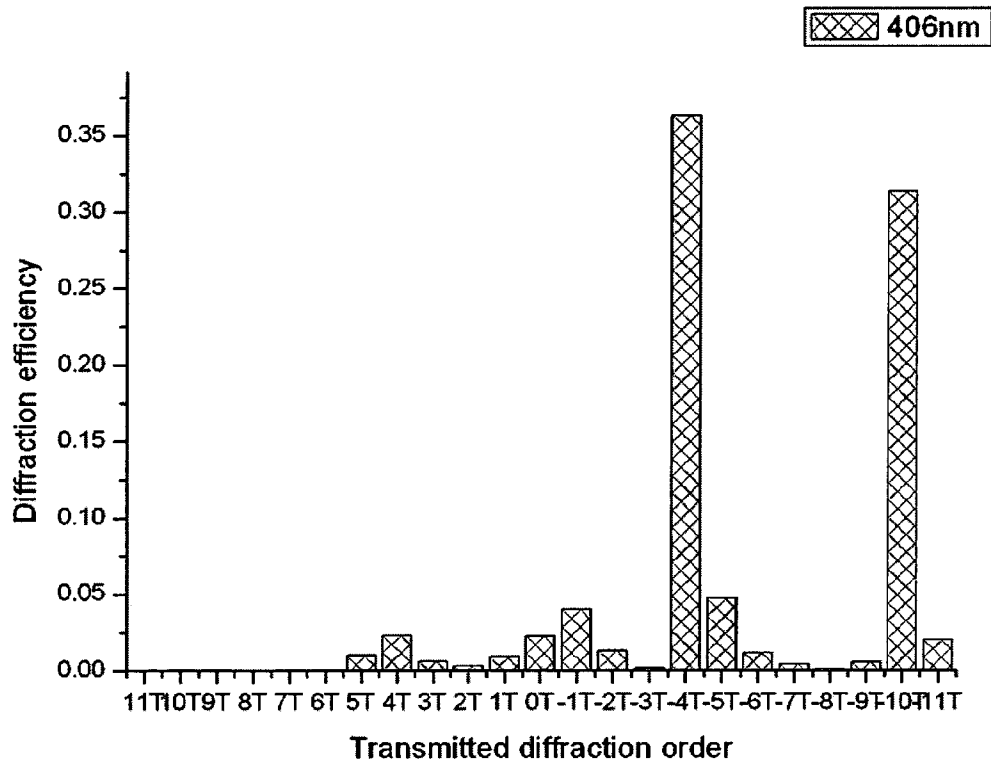
[Fig. 13]



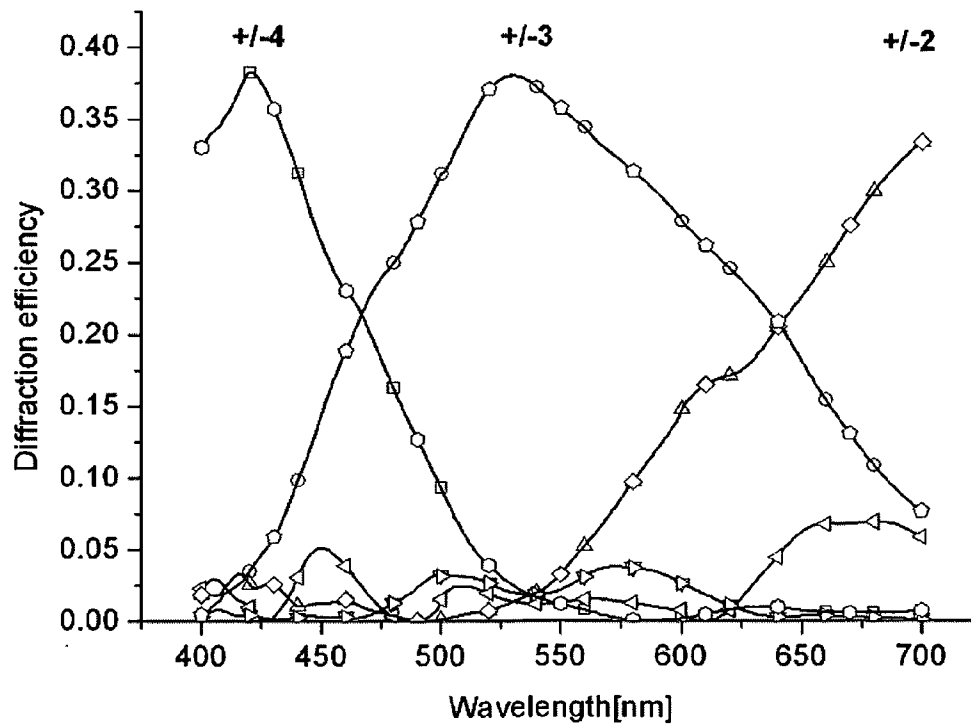
[Fig. 14]



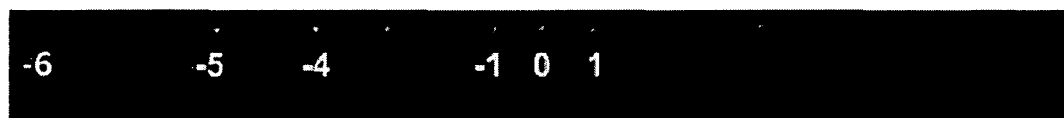
[Fig. 15]



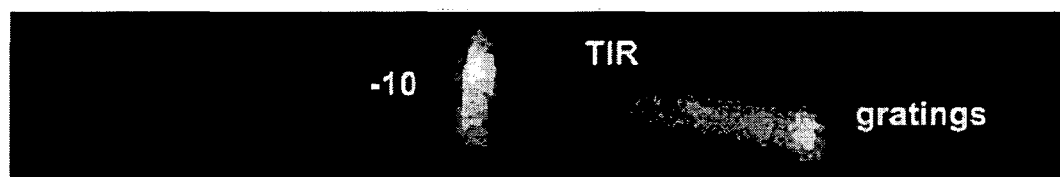
[Fig. 16]



[Fig. 17]



[Fig. 18]



INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2009/004749**A. CLASSIFICATION OF SUBJECT MATTER****G02B 5/18(2006.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G02B 5/18; F21V 8/00; G02B 5/32; G02B 6/28; G03B 21/62

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models
Japanese utility models and applications for utility models
(Chinese Patents and application for patent)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: diffraction, prism, groove, reflection, mirror, refraction, transmission

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	JP 2001-264884 A (VICTOR CO OF JAPAN LTD) 26 September 2001 See abstract; claims 1-2 and figures 1-7	1,6 2-5, 7-10
A	JP 62-047005 A (SUMITOMO ELECTRIC IND LTD) 28 February 1987 See abstract; claims 1-11 and figure 2	1-10
A	KR 10-2005-0087123 A (LG ELECTRONICS INC.) 31 August 2005 See abstract; claims 1-4 and figure 4	1-10
A	JP 2006-058844 A (HITACHI CHEM CO LTD) 02 March 2006 See abstract; claims 1-17 and figures 1-15	1-10



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

10 MARCH 2010 (10.03.2010)

Date of mailing of the international search report

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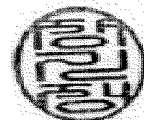
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Information on patent family members

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