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(71) Applicant: **APPLIED MATERIALS, INC.** [US/US]; 3050 Bowers Avenue, Santa Clara, California 95054 (US).

(72) Inventors: **BUDIARTO, Edward**; 43971 Rosemere Drive, Fremont, California 94539 (US). **VAEZ-IRAVANI, Mehdi**; 23484 Summit Road, Los Gatos, California 95033 (US). **BENCHER, Christopher**; 10208 Cold Harbor Avenue, Cupertino, California 95014 (US).

(74) Agents: **PATTERSON, B. Todd** et al.; Patterson & Sheridan, L.L.P., 24 Greenway Plaza, Suite 1600, Houston, Texas 77046 (US).

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(54) Title: ENHANCED ILLUMINATION EFFICIENCY IN MASKLESS, PROGRAMMABLE OPTICAL LITHOGRAPHY SYSTEMS

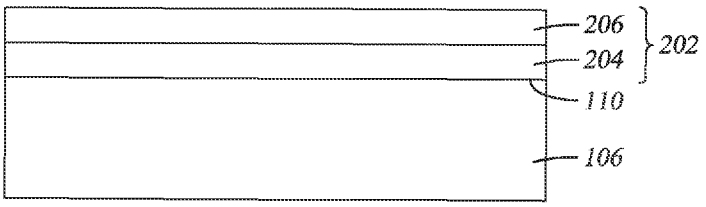


Fig. 2B

(57) Abstract: Embodiments described herein generally relate to a DMD. The DMD includes a base and a plurality of mirrors disposed on the base. Each mirror of the plurality of mirrors has a surface facing away from the base, and a structure is disposed on the surface of each mirror. The structure enhances the reflectance of the surface of each mirror, which enhances the efficiency of light manipulation and delivery.

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ENHANCED ILLUMINATION EFFICIENCY IN MASKLESS, PROGRAMMABLE OPTICAL LITHOGRAPHY SYSTEMS

BACKGROUND

Field

[0001] Embodiments described herein generally relate to apparatus for microlithography patterning and more particularly to a digital micro-mirror device (DMD).

Description of the Related Art

[0002] Photolithography is widely used in the manufacturing of semiconductor devices and display devices, such as liquid crystal displays (LCDs). Large area substrates are often utilized in the manufacture of LCDs. LCDs, or flat panels, are commonly used for active matrix displays, such as computers, touch panel devices, personal digital assistants (PDAs), cell phones, television monitors, and the like. Generally, flat panels may comprise a layer of liquid crystal material forming pixels sandwiched between two plates. When power from the power supply is applied across the liquid crystal material, an amount of light passing through the liquid crystal material may be controlled at pixel locations enabling images to be generated.

[0003] Microlithography techniques are generally employed to create electrical features incorporated as part of the liquid crystal material layer forming the pixels. According to this technique, a light-sensitive photoresist is typically applied to at least one surface of the substrate. Then, a pattern generator, such as a programmable writing engine in the form of a digital micro-mirror device (DMD), exposes selected areas of the light-sensitive photoresist as part of a pattern with light to cause chemical changes to the photoresist in the selective areas to prepare these selective areas for subsequent material removal and/or material addition processes to create the electrical features.

[0004] Insufficient light delivery to the selected areas can cause secondary effects, such as stray light and excess heating of various elements in the system. Therefore, an improved DMD is needed.

SUMMARY

[0005] Embodiments described herein generally relate to a DMD. The DMD includes a base and a plurality of mirrors disposed on the base. Each mirror of the plurality of mirrors has a surface facing away from the base, and a structure is disposed on the surface of each mirror. The structure enhances the reflectance of the surface of each mirror, which enhances the efficiency of light manipulation and delivery.

[0006] In one embodiment, a DMD includes a base and a plurality of mirrors disposed on the base. Each mirror of the plurality of mirrors includes a surface that is facing away from the base. The DMD further includes a structure disposed on the surface of each mirror, and the structure includes one or more pairs of alternating layers of dielectric material.

[0007] In another embodiment, a DMD includes a base and a plurality of mirrors disposed on the base. Each mirror of the plurality of mirrors includes a surface that is facing away from the base. The DMD further includes a structure disposed on the surface of each mirror, and the structure includes a first layer of dielectric material disposed on the surface and a second layer of dielectric material disposed on the first layer. A refractive index of the first layer of dielectric material is different from a refractive index of the second layer of dielectric material.

[0008] In another embodiment, a DMD includes a base and a plurality of mirrors disposed on the base. Each mirror of the plurality of mirrors includes a surface that is facing away from the base. The DMD further includes a structure disposed on the surface of each mirror, and the structure includes multiple pairs of layers of dielectric material. Each pair of the multiple pairs of layers of dielectric material includes a first

layer and a second layer. A refractive index of the first layer of dielectric material is different from a refractive index of the second layer of dielectric material.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] So that the manner in which the above recited features of the disclosure can be understood in detail, a more particular description of the disclosure, briefly summarized above, may be had by reference to embodiments, some of which are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only typical embodiments of this disclosure and are therefore not to be considered limiting of its scope, for the disclosure may admit to other equally effective embodiments.

[0010] Figure 1 schematically illustrates a DMD according to one embodiment.

[0011] Figures 2A – 2C are schematic side views of a mirror of the DMD of Figure 1 according to various embodiments.

[0012] Figures 3A – 3B are charts illustrating improvements in reflectance with the DMD of Figure 1 according to various embodiments.

[0013] To facilitate understanding, identical reference numerals have been used, where possible, to designate identical elements that are common to the figures. It is contemplated that elements and features of one embodiment may be beneficially incorporated in other embodiments without further recitation.

DETAILED DESCRIPTION

[0014] Embodiments described herein generally relate to a DMD. The DMD includes a base and a plurality of mirrors disposed on the base. Each mirror of the plurality of mirrors has a surface facing away from the base, and a structure is disposed on the surface of each mirror. The structure enhances the reflectance of the surface of each mirror, which enhances the efficiency of light manipulation and delivery.

[0015] Figure 1 schematically illustrates a DMD 100 according to one embodiment. The DMD 100 may include a base 104 and plurality of mirrors 106, 108, as shown in an enlarged and simplified portion 102. The plurality of mirrors 106, 108 may be individually controlled to tilt in fixed angles, such as ±12 degrees. As shown in Figure 1, the mirrors 106 are flat while the mirrors 108 are tilted at an angle by the transistor controller disposed under each mirror 108. The tilting of the mirrors 106, 108 may determine whether the light reflected by the mirrors 106, 108 is directed to a surface of a substrate to be patterned. In one embodiment, the tilted mirrors 108 at +12 degrees direct the light to the surface of the substrate and the titled mirrors 108 at -12 degrees and the flat mirrors 106 direct the light to a light dump, which is not on the surface of the substrate. The plurality of mirrors 106, 108 may each include a surface 110 that is facing away from the base 104. The surface 110 may be made of a reflective metal, such as aluminum, in order to reflect a light, such as a laser beam, from a light source to the surface of the substrate or to the light dump. A structure (shown in Figures 2A – 2C) may be disposed on the surface 110 in order to increase reflectance of the mirrors 106, 108.

[0016] Figures 2A – 2C are schematic side views of the mirror 106 or mirror 108 of the DMD 100 of Figure 1 according to various embodiments. As shown in Figure 2A, the mirror 106 (or mirror 108) has the surface 110 that is facing away from the base 104. A structure 202 may be disposed on the surface 110. In one embodiment, the structure 202 includes a single layer of dielectric material. In other embodiments, the structure 202 is a multi-layer structure including one or more pairs of alternating thin dielectric layers having varying refractive indices. The structure 202 disposed on the surface 110 increases reflectivity and decreases absorption. When absorption of the mirrors 106, 108 is decreased, the heat load on the DMD 100 is also decreased, which in turn enables longer service lifetime of the DMD 100, less cooling for the DMD 100, and higher power illumination into the DMD 100 for higher power applications. The structure 202 formed on the surface 110 is not thick enough to alter the mechanical characteristics of the mirrors 106, 108 of the DMD

100. Additionally, since the structure 202 is made of a dielectric material, no issues should arise in the process of manufacturing the DMD 100.

[0017] As shown in Figure 2B, the structure 202 is a bilayer structure including a first layer 204 disposed on the surface 110 and a second layer 206 disposed on the first layer 204. The refractive index of the first layer 204 is different from the refractive index of the second layer 206. In one embodiment, the imaginary part k of the refractive index of layers 204, 206 may be the same, such as 0, but the real part n of the refractive index of layers 204, 206 may be different, and the difference in n between layers 204, 206 may be at least 1. In one embodiment, the light reflected by the DMD 100 has a wavelength in the ultraviolet (UV) range, such as between about 360 nm and about 410 nm, and the first layer 204 is silicon dioxide and the second layer 206 is titanium dioxide. In another embodiment, the light reflected by the DMD 100 has a wavelength in the visible range, such as between about 400 nm and about 750 nm, and the first layer 204 is magnesium fluoride and the second layer 206 is vanadium (V) oxide. The thickness of the first layer 204 may range from about 40 nm to about 86 nm and the thickness of the second layer 206 may range from about 35 nm to about 60 nm. In one embodiment, the first layer 204 is silicon dioxide and has a thickness of about 40 nm and the second layer 206 is titanium dioxide and has a thickness of about 40 nm. In another embodiment, the first layer 204 is silicon dioxide and has a thickness of about 53 nm and the second layer 206 is titanium dioxide and has a thickness of about 38 nm. In another embodiment, the first layer 204 is silicon dioxide and has a thickness of about 82 nm and the second layer 206 is titanium dioxide and has a thickness of about 58 nm. In another embodiment, the first layer 204 is magnesium fluoride and has a thickness of about 85 nm and the second layer 206 is vanadium (V) oxide and has a thickness of about 47 nm.

[0018] Figure 2C is a schematic side view of the mirror 106 or mirror 108 according to another embodiment. As shown in Figure 2C, the structure 202 may include a first layer 208 disposed on the surface 110 of the mirror 106 or mirror 108, a second layer 210 disposed on the first layer 208, a third layer 212 disposed on the

second layer 210, and a fourth layer 214 disposed on the third layer 212. First and third layers 208, 212 may be made of the same material and may have the same thickness, and second and fourth layers 210, 214 may be made of the same material and may have the same thickness. The refractive index of layers 208, 212 may be different from the refractive index of layers 210, 214. In one embodiment, the imaginary part k of the refractive index of layers 208, 210, 212, 214 may be the same, such as 0, but the real part n of the refractive index of layers 208, 212 may be different from the real part n of the refractive index of layers 210, 214, and the difference in n may be at least 1. Thus, the structure 202 may include two pairs of alternating layers having different refractive indices. The structure 202 may include more than two pairs of alternating layers as long as the thickness of the structure 202 does not alter the mechanical characteristics of the mirrors 106, 108 of the DMD 100.

[0019] In one embodiment, the light reflected by the DMD 100 has a wavelength in the ultraviolet (UV) range, such as between about 360 nm and about 410 nm, and the first and third layers 208, 212 are silicon dioxide and the second and fourth layers 210, 214 are titanium dioxide. In another embodiment, the light reflected by the DMD 100 has a wavelength in the visible range, such as between about 400 nm and about 750 nm, and the first and third layers 208, 212 are magnesium fluoride and the second and fourth layers 210, 214 are vanadium (V) oxide. The thickness of the first layer 208 may range from about 40 nm to about 90 nm, the thickness of the second layer 210 may range from about 35 nm to about 90 nm, the thickness of the third layer 212 may range from about 40 nm to about 90 nm, and the thickness of the fourth layer 214 may range from about 35 nm to about 90 nm. In one embodiment, the first and third layers 208, 212 are silicon dioxide and each has a thickness of about 40 nm, and the second and fourth layers 210, 214 are titanium dioxide and each has a thickness of about 40 nm. In another embodiment, the first and third layers 208, 212 are silicon dioxide, and the first layer 208 has a thickness of about 53 nm and the third layer 212 has a thickness of about 67 nm. The second and fourth layers 210, 214 are titanium dioxide, and the second layer 210 has a thickness

of about 38 nm and the fourth layer 214 has a thickness of about 37 nm. In another embodiment, the first and third layers 208, 212 are silicon dioxide and each layer 208, 212 has a thickness of about 65 nm, and the second and fourth layers 210, 214 are titanium dioxide and each layer 210, 214 has a thickness of about 86 nm. In another embodiment, the first and third layers 208, 212 are magnesium fluoride and each layer 208, 212 has a thickness of about 88 nm and the second and fourth layers 210, 214 are vanadium (V) oxide and each layers 210, 214 has a thickness of about 47 nm.

[0020] Figure 3A is a chart 300 illustrating increased reflectance of light having a wavelength between 360 nm and 410 nm, as a result of having the structure 202 disposed on the mirrors 106, 108 of the DMD 100. As shown in Figure 3A, line 302 indicates the reflectance of a mirror that is made of 500 nm thick aluminum. Lines 304, 306, 308 and 310 indicate the increased reflectance of a mirror that is made of a 500 nm thick aluminum mirror having the structure 202 disposed thereon. For line 304, the structure 202 is a bilayer structure and includes a silicon dioxide layer and a titanium dioxide layer. Each layer has a thickness of about 40 nm. For line 306, the structure 202 is a bilayer structure and includes a silicon dioxide layer and a titanium dioxide layer. The silicon dioxide layer has a thickness of about 53 nm and the titanium dioxide layer has a thickness of about 38 nm. For line 308, the structure 202 includes a first silicon dioxide layer, a first titanium dioxide layer disposed on the first silicon dioxide layer, a second silicon dioxide layer disposed on the first titanium dioxide layer, and a second titanium dioxide layer disposed on the second silicon dioxide layer. Each layer in the structure 202 has a thickness of about 40 nm. For line 310, the structure 202 includes a first silicon dioxide layer, a first titanium dioxide layer disposed on the first silicon dioxide layer, a second silicon dioxide layer disposed on the first titanium dioxide layer, and a second titanium dioxide layer disposed on the second silicon dioxide layer. The first silicon dioxide layer has a thickness of about 53 nm, the first titanium dioxide layer has a thickness of about 38 nm, the second silicon dioxide layer has a thickness of about 67 nm, and the second titanium dioxide layer has a thickness of about 37 nm. The reflectance indicated by

lines 304, 306, 308, 310 is consistently higher than the reflectance indicated by line 302 across the entire wavelength range shown in Figure 3A.

[0021] Figure 3B is a chart 320 illustrating increased reflectance of light having a wavelength between 400 nm and 750 nm, as a result of having the structure 202 disposed on the mirrors 106, 108 of the DMD 100. As shown in Figure 3B, line 322 indicates the reflectance of a mirror that is made of 500 nm thick aluminum. Lines 324, 326, 328 and 330 indicate the increased reflectance of a mirror that is made of a 500 nm thick aluminum mirror having the structure 202 disposed thereon. For line 324, the structure 202 includes a first silicon dioxide layer, a first titanium dioxide layer disposed on the first silicon dioxide layer, a second silicon dioxide layer disposed on the first titanium dioxide layer, and a second titanium dioxide layer disposed on the second silicon dioxide layer. The first and second silicon dioxide layers each has a thickness of about 65 nm and the first and second titanium dioxide layers each has a thickness of about 86 nm. For line 326, the structure 202 is a bilayer structure and includes a silicon dioxide layer and a titanium dioxide layer. The silicon dioxide layer has a thickness of about 82 nm and the titanium dioxide layer has a thickness of about 58 nm. For line 328, the structure 202 is a bilayer structure and includes a magnesium fluoride layer and a vanadium (V) oxide layer. The magnesium fluoride layer has a thickness of about 85 nm and the vanadium (V) oxide layer has a thickness of about 47 nm. For line 330, the structure 202 includes a first magnesium fluoride layer, a first vanadium (V) oxide layer disposed on the first magnesium fluoride layer, a second magnesium fluoride layer disposed on the first vanadium (V) oxide layer, and a second vanadium (V) oxide layer disposed on the second magnesium fluoride layer. The first and second magnesium fluoride layers each has a thickness of about 88 nm and the first and second vanadium (V) oxide layers each has a thickness of about 47 nm. The reflectance indicated by lines 326, 328, 330 is consistently higher than the reflectance indicated by line 322 across the entire wavelength range shown in Figure 3B.

[0022] While the foregoing is directed to embodiments of the present disclosure, other and further embodiments may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

What is claimed is:

1. A digital micro-mirror device, comprising:

a base;

a plurality of mirrors disposed on the base, wherein each mirror of the plurality of mirrors includes a surface facing away from the base; and

a structure disposed on the surface of each mirror, wherein the structure includes one or more pairs of alternating layers of dielectric material.

2. The digital micro-mirror device of claim 1, wherein the structure includes one pair of layers of dielectric material.

3. The digital micro-mirror device of claim 2, wherein a refractive index of a layer of the one pair of layers of dielectric material is different from a refractive index of another layer of the one pair of layers of dielectric material.

4. The digital micro-mirror device of claim 3, wherein the one pair of layers of dielectric material includes a silicon dioxide layer disposed on the surface of each mirror and a titanium dioxide layer disposed on the silicon dioxide layer.

5. The digital micro-mirror device of claim 3, wherein the one pair of layers of dielectric material includes a magnesium fluoride layer disposed on the surface of each mirror and a vanadium (V) oxide layer disposed on the magnesium fluoride layer.

6. The digital micro-mirror device of claim 1, wherein the structure includes multiple pairs of layers of dielectric material.

7. The digital micro-mirror device of claim 6, wherein a refractive index of a layer of a pair of layers of the multiple pairs of layers of dielectric material is different from

a refractive index of another layer of the pair of layers of the multiple pairs of layers of dielectric material.

8. The digital micro-mirror device of claim 6, wherein each pair of layers of the multiple pairs of dielectric material includes a silicon dioxide layer and a titanium dioxide layer disposed on the silicon dioxide layer.

9. The digital micro-mirror device of claim 6, wherein each pair of layers of the multiple pairs of dielectric material includes a magnesium fluoride layer and a vanadium (V) oxide layer disposed on the magnesium fluoride layer.

10. A digital micro-mirror device, comprising:

a base;

a plurality of mirrors disposed on the base, wherein each mirror of the plurality of mirrors includes a surface facing away from the base; and

a structure disposed on the surface of each mirror, wherein the structure includes a first layer of dielectric material disposed on the surface and a second layer of dielectric material disposed on the first layer, wherein a refractive index of the first layer of dielectric material is different from a refractive index of the second layer of dielectric material.

11. The digital micro-mirror device of claim 10, wherein the first layer of dielectric material is a silicon dioxide layer disposed on the surface of each mirror and the second layer of dielectric material is a titanium dioxide layer disposed on the silicon dioxide layer.

12. The digital micro-mirror device of claim 11, wherein the silicon dioxide layer has a thickness ranging from about 40 nm to about 86 nm and the titanium dioxide layer has a thickness ranging from about 35 nm to about 60 nm.

13. The digital micro-mirror device of claim 10, wherein the first layer of dielectric material is a magnesium fluoride layer disposed on the surface of each mirror and the second layer of dielectric material is a vanadium (V) oxide layer disposed on the magnesium fluoride layer.

14. A digital micro-mirror device, comprising:

a base;

a plurality of mirrors disposed on the base, wherein each mirror of the plurality of mirrors includes a surface facing away from the base; and

a structure disposed on the surface of each mirror, wherein the structure includes multiple pairs of layers of dielectric material, wherein each pair of the multiple pairs of layers of dielectric material includes a first layer and a second layer, and wherein a refractive index of the first layer is different from a refractive index of the second layer.

15. The digital micro-mirror device of claim 14, wherein the first layer has a thickness ranging from about 40 nm to about 86 nm and the second layer has a thickness ranging from about 35 nm to about 60 nm.

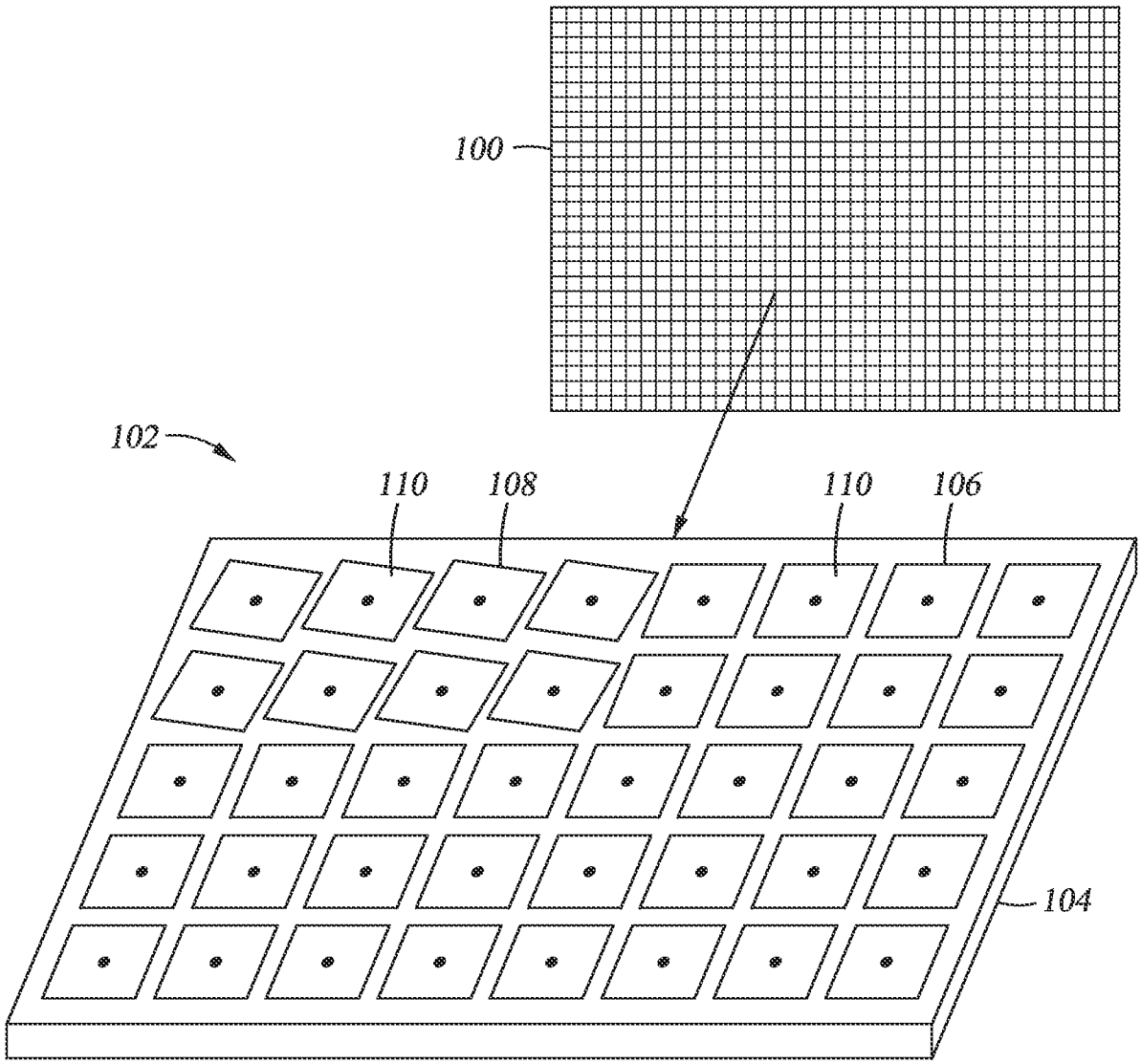


Fig. 1

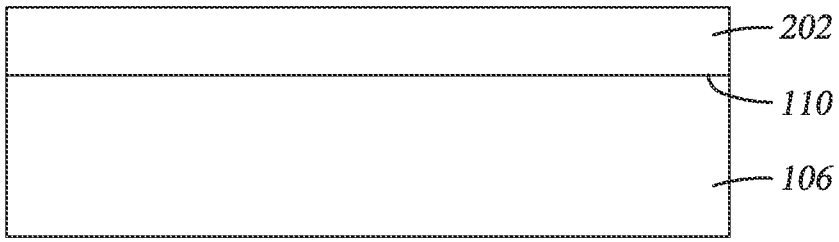


Fig. 2A

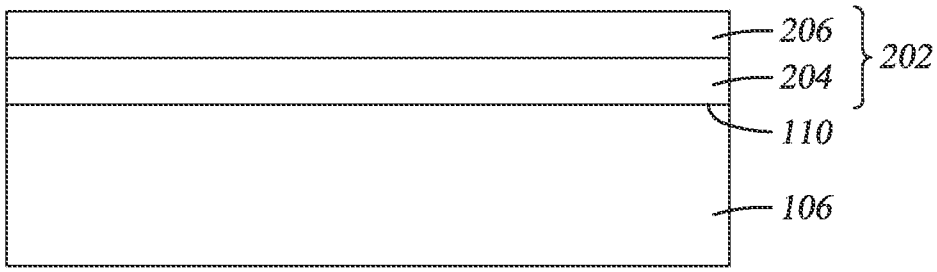


Fig. 2B

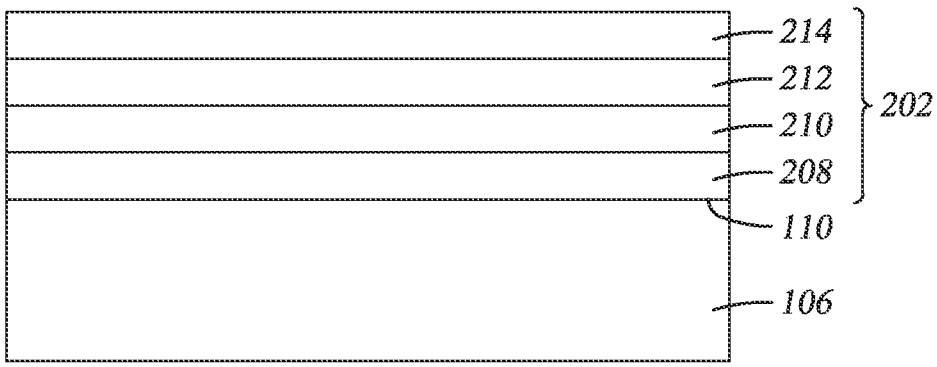


Fig. 2C

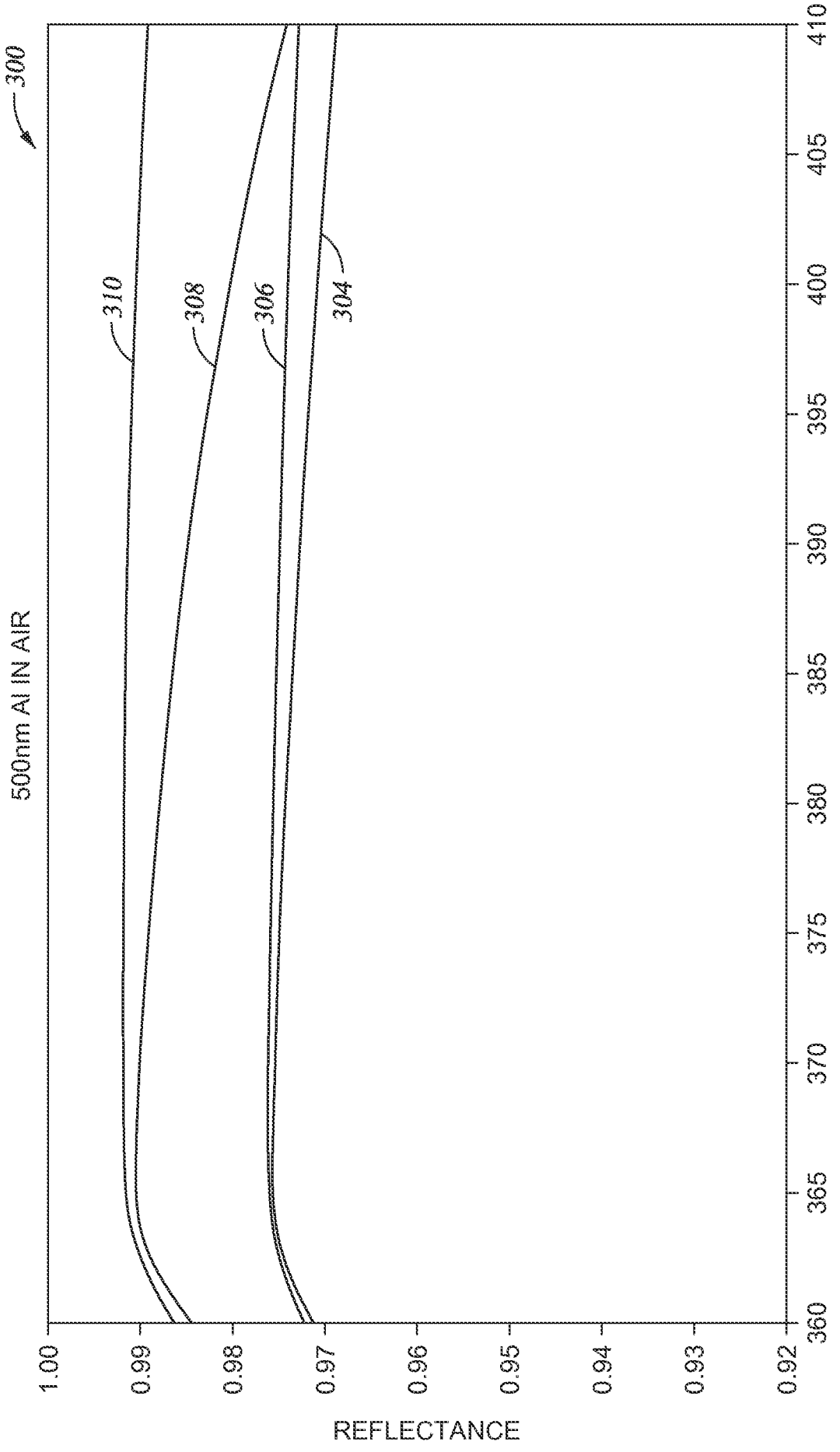

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306
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0.98
0.97
0.96
0.95
0.94
0.93
0.92
REFLECTANCE
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375
380
385
390
395
400
405
410
WAVELENGTH (nm)

Fig. 3A

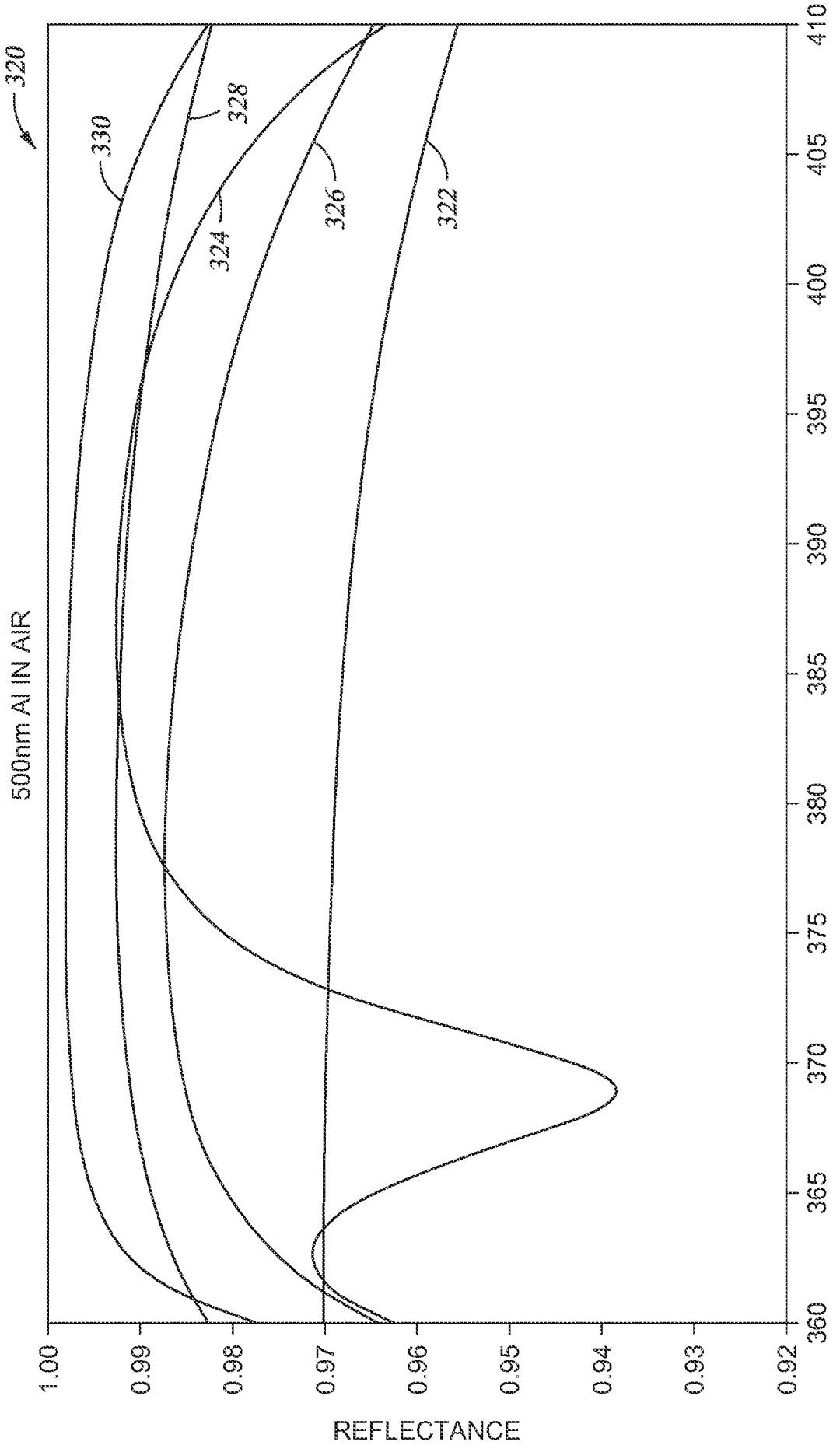

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330
328
324
326
322
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0.99
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0.97
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0.94
0.93
0.92
REFLECTANCE
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365
370
375
380
385
390
395
400
405
410
WAVELENGTH (nm)

Fig. 3B

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/030748

A. CLASSIFICATION OF SUBJECT MATTER

H01L 21/027(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)
H01L 21/027; G02B 26/08; G02B 5/08; G02B 26/00; B81B 3/00; B32B 37/02; G03F 7/20

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: micro mirror device, dielectric, second dielectric, different thickness, pair of layers of dielectric,

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2010-0255426 A1 (KANTI JAIN et al.) 07 October 2010 See abstract; paragraphs [0019], [0080]-[0100]; claim 1; and figures 18-19.	1-15
A	US 2006-0227406 A1 (SATYADEV PATEL et al.) 12 October 2006 See abstract; paragraphs [0045]-[0046]; claims 4, 5; and figure 5.	1-15
A	US 2006-0245036 A1 (JASON M. NEIDRICH) 02 November 2006 See abstract; paragraphs [0012]-[0014]; claim 1; and figure 1A.	1-15
A	JP 2004-151723 A (HEWLETT-PACKARD DEVELOPMENT CO., L.P.) 27 May 2004 See paragraphs [0018]-[0020]; claim 1; and figure 1.	1-15
A	US 2002-0012490 A1 (KENNETH, R. FARMER, III et al.) 31 January 2002 See abstract; paragraphs [0019], [0020]; claim 1; and figure 1.	1-15

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26 November 2015 (26.11.2015)	**26 November 2015 (26.11.2015)**

Name and mailing address of the ISA/KR
International Application Division
Korean Intellectual Property Office
189 Cheongsa-ro, Seo-gu, Daejeon Metropolitan City, 35208,
Republic of Korea
Facsimile No. +82-42-472-7140

Authorized officer
CHOI, Sang Won
Telephone No. +82-42-481-8291

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2015/030748

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2010-0255426 A1	07/10/2010	US 8610986 B2	17/12/2013
US 2006-0227406 A1	12/10/2006	US 7295363 B2	13/11/2007
US 2006-0245036 A1	02/11/2006	CN 101164171 A	16/04/2008
		EP 1875294 A2	09/01/2008
		TW 200707633 A	16/02/2007
		US 7402880 B2	22/07/2008
		WO 2006-113806 A2	26/10/2006
		WO 2006-113806 A3	21/12/2006
JP 2004-151723 A	27/05/2004	EP 1416311 A1	06/05/2004
		JP 4044889 B2	06/02/2008
		TW 200406594 A	01/05/2004
		TW 234005 A	11/06/2005
		US 2004-0080806 A1	29/04/2004
		US 6666561 B1	23/12/2003
		US 6843576 B2	18/01/2005
US 2002-0012490 A1	31/01/2002	US 6480646 B2	12/11/2002