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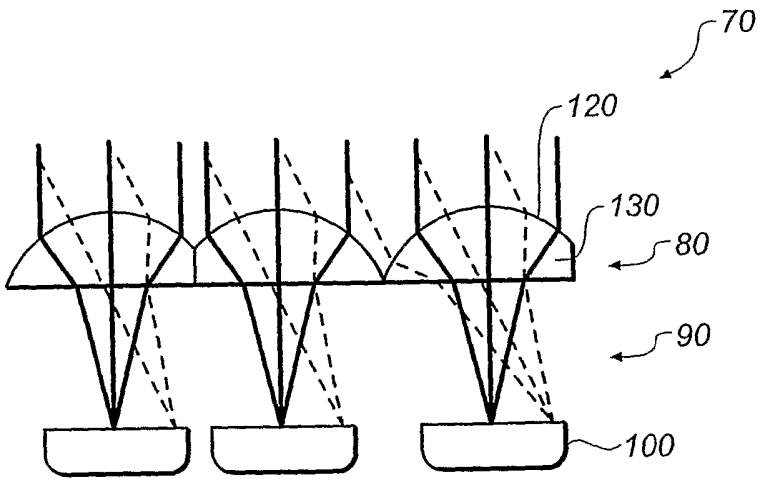
(54) Title: ASYMMETRICAL MICROLENSES ON PIXEL ARRAYS



(57) Abstract: An image sensor includes a plurality of photosensitive sites (100), a plurality of asymmetrical-shaped microlenses (130) positioned spanning the photosensitive sites(100); wherein incoming light is directed in a predetermined direction by an asymmetrical surface of the asymmetrical-shaped microlenses (120) onto the photosensitive sites (100) for capturing the light in a substantially uniform manner.

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ASYMMETRICAL MICROLENSES ON PIXEL ARRAYS

FIELD OF THE INVENTION

The invention relates generally to the field of microlenses spanning photosensitive sites of an image sensor and, more particularly, to asymmetrical microlenses spanning the photosensitive site that captures incident light in a substantially uniform manner.

BACKGROUND OF THE INVENTION

Referring to Fig. 1, image sensors 10 typically include pixels 20 having a photosensitive area or photodiode 30 for capturing incident light and associated circuitry 40 adjacent the photosensitive area for processing and the like. In some cases, pixels 20 of an image sensor 10 are arranged asymmetrically to maximize the performance of the pixel while accommodating the associated circuitry 40. However, in this case, four of the pixels 20 typically form a regular grid pattern forming a supercell 50. Referring to Fig. 2, a microlens 60 is positioned spanning and spatially centered over the "photosensitive portion" of the pixels 20. Referring to Fig. 3, alternatively, microlenses 65 may be positioned spanning and centered over the entire "pixel" creating a regular array of microlenses.

Although the prior art arrangement of microlens 60 as in Fig. 2 is satisfactory, it includes drawbacks in that the microlens 60 is a small fraction of the area of the pixel, and therefore the photodiode 30 captures a small fraction of the incident light.

Still further, although the prior art arrangement of microlenses 65 (as in Fig. 3) over asymmetrically positioned pixels is satisfactory, they also include drawbacks. Referring to Fig. 4, as long as photodiodes 30 are symmetric with respect to the microlens 60 such as being centered in the pixel, then the performance of all pixels degrade in the same manner as the angle of the incident light is increased. As shown in Fig. 5, light passing (indicated by the dashed lines)

through the microlenses 65 at certain angles is not directed onto the photodiode 30 causing undesirable degradation of the captured image when the photodiodes 30 are not arranged symmetrically with the microlens.

Consequently, a need exists for improved focusing of light on asymmetrical positioned pixels.

SUMMARY OF THE INVENTION

The present invention is directed to overcoming one or more of the problems set forth above. Briefly summarized, according to one aspect of the present invention, the invention resides in an image sensor comprising (a) a plurality of photosensitive sites; (b) a plurality of asymmetrical-shaped microlenses positioned spanning the photosensitive sites; wherein incoming light is directed in a predetermined direction by an asymmetrical surface of the asymmetrical-shaped microlenses onto the photosensitive sites for capturing the light in a substantially uniform manner.

These and other aspects, objects, features and advantages of the present invention will be more clearly understood and appreciated from a review of the following detailed description of the preferred embodiments and appended claims, and by reference to the accompanying drawings.

Advantageous Effect Of The Invention

The present invention has the advantage of increasing the light gathering capacity of a pixel array and eliminating artifacts that occur when the incident angle of illumination is varied or varies. It is also includes the advantage of permitting more design freedom for efficient use of the pixel space.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a top view of a prior art pixel array with apertures in an asymmetrical arrangement;

Fig. 2 is a top view of Fig. 1 with microlenses spanning and centered over the photodiodes of array of pixels;

Fig. 3 is a top view of Fig. 1 with microlenses spanning and centered over the pixels in the array;

Fig. 4 is a side view of a prior art pixel array with a symmetric arrangement of photodiodes and microlenses;

Fig. 5 is a side view of a prior art pixel array with a symmetric microlenses and asymmetrical arrangement of photodiodes;

Fig. 6 is a side view of the pixel array of the present invention with an asymmetric arrangement of photodiodes and an asymmetric arrangement of microlenses (the optical axis of each microlens is aligned with the center of the photodiode);

Fig. 7 is a top view of Fig. 6; and

Fig. 8 is a top view of an alternative embodiment of Fig. 6 of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Referring to Figs. 6 and 7, there are shown a side view and a top view of an image sensor 70 having a plurality or array of microlenses 80 of the present invention positioned respectively spanning a plurality of pixels 90 each having a photosensitive area or photodiode 100. As stated above, the pixels 90 are arranged asymmetrically. However, it is noted that pixels are grouped together so as to form an array of supercells 110. It is noted that only two supercells 110a and 110b each comprising two pixels is shown for clarity in Figs. 6 and 7. For completeness, it is noted that the photosensitive areas 100 are disposed along a top portion of a silicon substrate, as is well known in the art. The pixels 90 are arranged so that by design they include an asymmetrical arrangement of the photosensitive areas 100. An optical surface 120 of the microlens 130 is asymmetrically shaped. Prior art microlens (60 and 65) are substantially hemispherically shaped. As seen more clearly in Fig. 6, the microlens 130 of the

present invention is substantially a truncated hemisphere that allows an asymmetrical arrangement. In other words, the each microlens 130 includes a substantially arcuate-shaped portion along a peripheral edge and includes two substantially straight portions positioned substantially perpendicular to each other along a remaining edge. For clarity, it is noted that the present invention microlens 130 has been trimmed along one or more edges as compared to the prior art microlens (60 and 65). This aligns the optical axis of the microlens 130 with the photodiode 100. Referring solely to Fig. 7, it is noted that, within the two pixels comprising the supercell 110, the microlenses 130 abut each other so that each individual microlens (130a, 130b, 130c and 130d) is symmetry with respect to an imaginary y-axis of the supercell 110, but still not symmetrical within any individual pixel 90 as stated hereinabove. In other words, each two-pixel supercell 110 includes two asymmetrical-shaped microlenses 130 grouped spanning a supercell 110 and a pair of straight portions, one from each microlens, are positioned so that a peripheral portion formed by the two microlenses is two arcuate-shaped edges and two straight edges

The above-described pixel array functions so that incoming light that passes through a microlens 130 is directed substantially uniformly, that is consistently from pixel to pixel, onto the photodiode 100, as illustrated by the solid and dashed lines, even though the spacing (i.e., distance) from photodiode to photodiode is not constant or is varying. In other words, the light is distributed substantially consistently across the photodiode 100 independent of which pixel within the supercell it is, with light passing from substantially directly overhead being directed substantially consistently onto a portion of the photodiode 100 and light that passes at angles through the microlens 130 is directed substantially consistently onto portions of the photodiode 100.

As shown in Fig. 8, an alternative embodiment of the supercell 110 arrangement is shown. In this embodiment, there are four pixels 90 symmetrical around both imaginary x and y axes.

Referring to Fig. 9, there is shown a side view of a digital camera 140 containing the image sensor 70 of the present invention for illustrating a typical commercial embodiment.

The invention has been described with reference to a preferred embodiment. However, it will be appreciated that variations and modifications can be effected by a person of ordinary skill in the art without departing from the scope of the invention.

PARTS LIST

10	image sensor
20	pixel
30	photosensitive area or photodiode
40	associated circuitry
50	regular grid pattern forming a supercell
60	microlens centered on photodiode
65	microlens centered on pixel
70	image sensor
80	array of microlenses
90	plurality of pixels
100	photosensitive area or photodiode
110	supercell of pixels
110a	supercell
110b	supercell
120	optical surface of microlens
130	microlens
130a	microlens
130b	microlens
130c	microlens
130d	microlens
140	digital camera

CLAIMS:

1. An image sensor comprising:

(a) a plurality of photosensitive sites; and

(b) a plurality of asymmetrical-shaped microlenses positioned spanning the photosensitive sites; wherein incoming light is directed in a predetermined direction by an asymmetrical surface of the asymmetrical-shaped microlenses onto the photosensitive sites for capturing the light in a substantially uniform manner.

2. The image sensor as in claim 1, wherein distances between the photosensitive sites are not constant.

3. The image sensor as in claim 1, wherein the photosensitive sites are arranged into groups, each group forming a supercell that have a regular grid pattern.

4. The image sensor as in claim 2, wherein the photosensitive sites are arranged into groups, each group forming a supercell that have a regular grid pattern.

5. The image sensor as in claim 1, wherein the asymmetrical shape includes a substantially arcuate-shaped portion along a peripheral edge and includes two substantially straight portions positioned substantially perpendicular to each other along a remaining edge.

6. The image sensor as in claim 3, wherein the asymmetrical shape includes a substantially arcuate-shaped portion along a peripheral edge and includes two substantially straight portions positioned substantially perpendicular to each other along a remaining edge.

7. The image sensor as in claim 5, wherein four asymmetrical-shaped microlenses are grouped spanning a supercell and a pair of straight portions, one from each microlens, are positioned facing each other so that a peripheral portion formed by the four microlenses is four arcuate-shaped edges.

8. The image sensor as in claim 5, wherein two asymmetrical-shaped microlenses are grouped spanning a supercell and a pair of straight portions, one from each microlens, are positioned so that a peripheral portion formed by the two microlenses is two arcuate-shaped edges and two straight edges.

9. A digital camera comprising:

an image sensor comprising:

(a) a plurality of photosensitive sites; and

(b) a plurality of asymmetrical-shaped microlenses positioned spanning the photosensitive sites; wherein incoming light is directed in a predetermined direction by an asymmetrical surface of the asymmetrical-shaped microlenses onto the photosensitive sites for capturing the light in a substantially uniform manner.

10. The digital camera as in claim 9, wherein distances between the photosensitive sites are not constant.

11. The digital camera as in claim 9, wherein the photosensitive sites are arranged into groups, each group forming a supercell that have a regular grid pattern.

12. The digital camera as in claim 10, wherein the photosensitive sites are arranged into groups, each group forming a supercell that have a regular grid pattern.

13. The digital camera as in claim 9, wherein the asymmetrical shape includes a substantially arcuate-shaped portion along a peripheral edge and includes two substantially straight portions positioned substantially perpendicular to each other along a remaining edge.

14. The digital camera as in claim 11, wherein the asymmetrical shape includes a substantially arcuate-shaped portion along a peripheral edge and includes two substantially straight portions positioned substantially perpendicular to each other along a remaining edge.

15. The digital camera as in claim 13, wherein four asymmetrical-shaped microlenses are grouped spanning a supercell and a pair of straight portions, one from each microlens, are positioned facing each other so that a peripheral portion formed by the four microlenses is four arcuate-shaped edges.

16. The digital camera as in claim 13, wherein two asymmetrical-shaped microlenses are grouped spanning a supercell and a pair of straight portions, one from each microlens, are positioned so that a peripheral portion formed by the two microlenses is two arcuate-shaped edges and two straight edges.

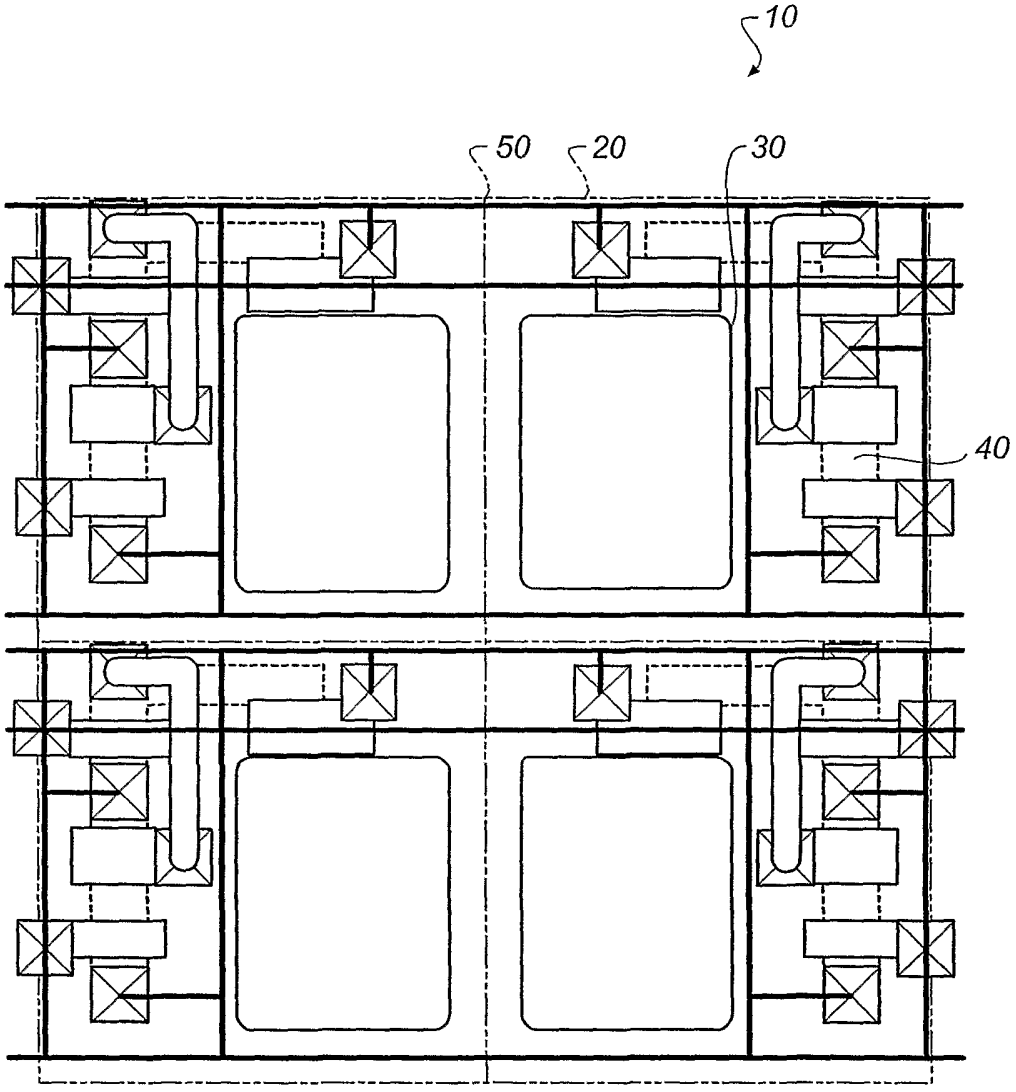

FIG. 1
(PRIOR ART)

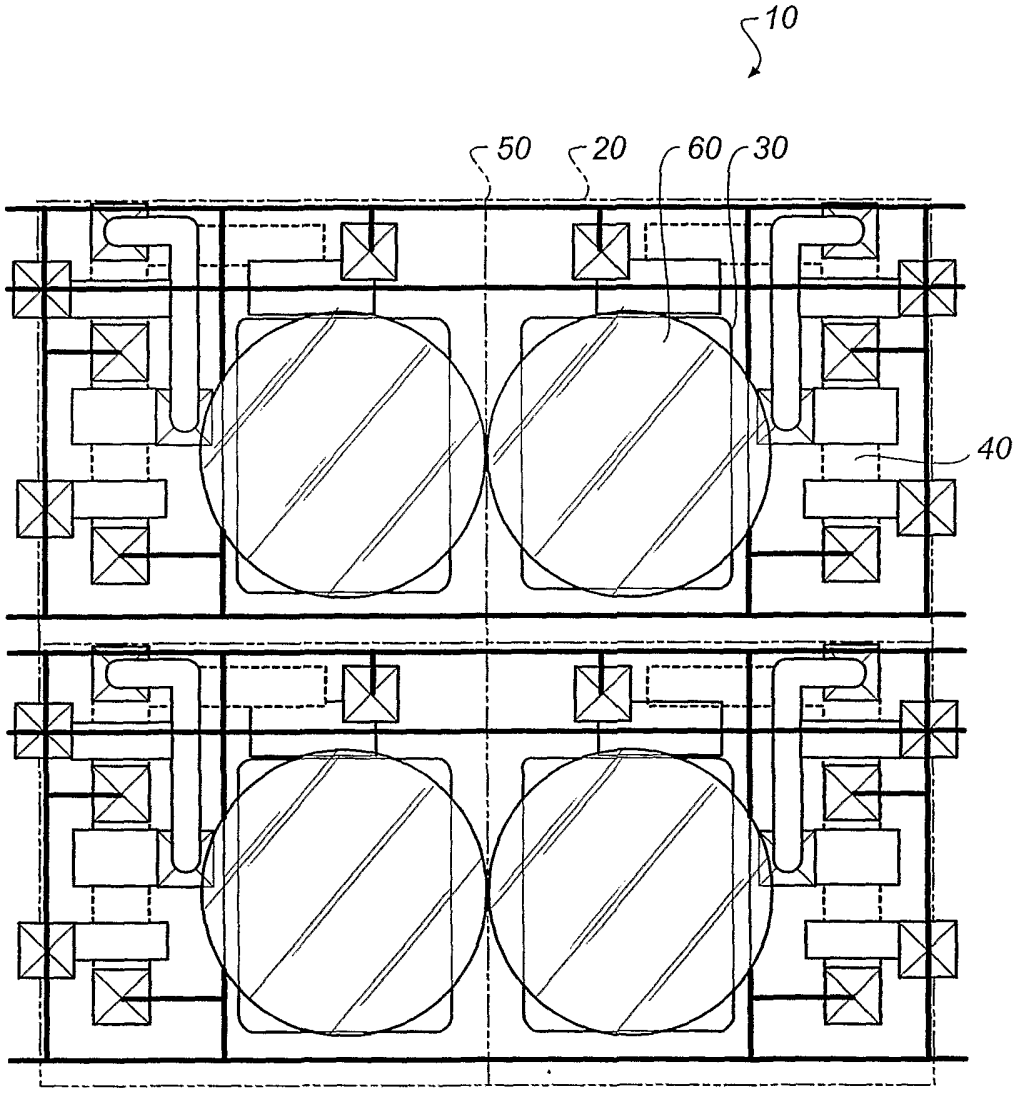

FIG. 2
(PRIOR ART)

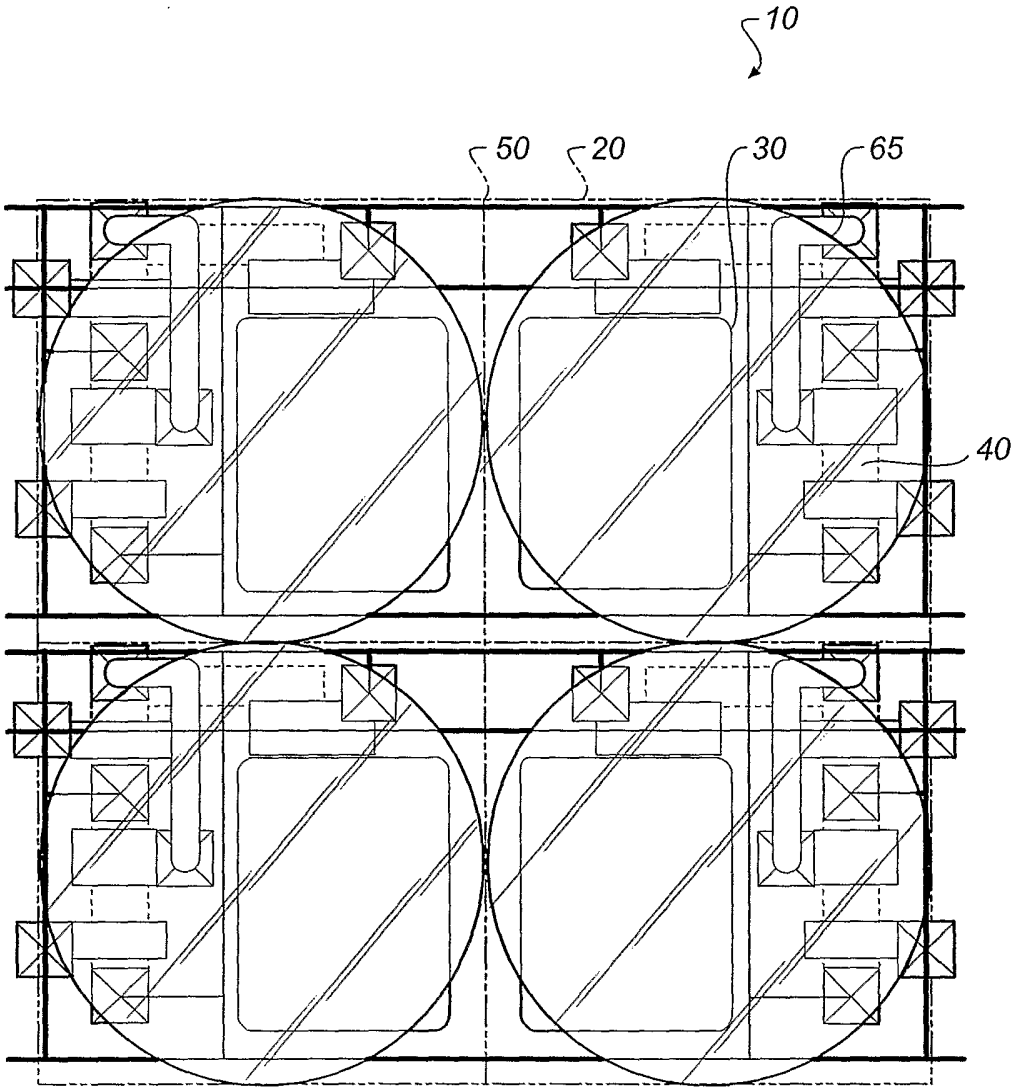

FIG. 3
(PRIOR ART)

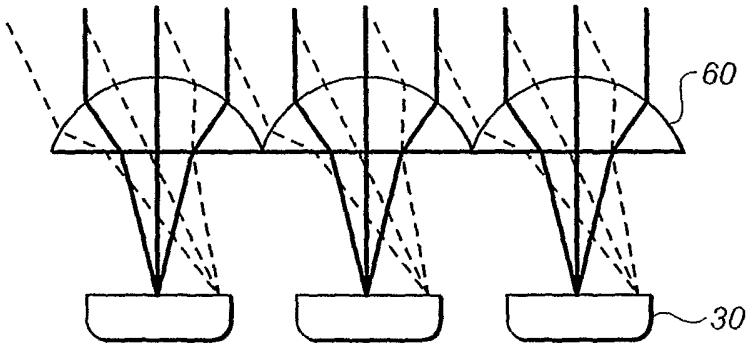

FIG. 4
(PRIOR ART)

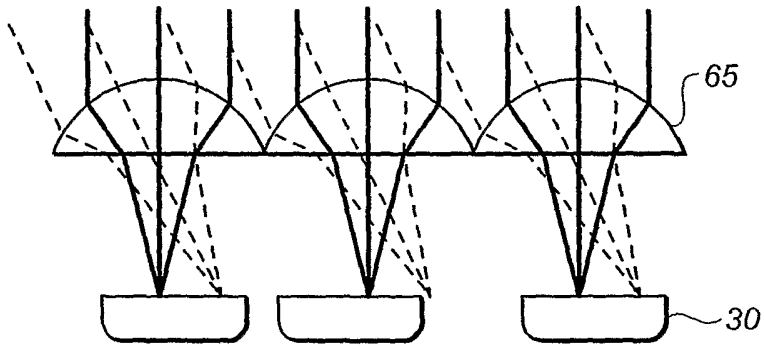

FIG. 5
(PRIOR ART)

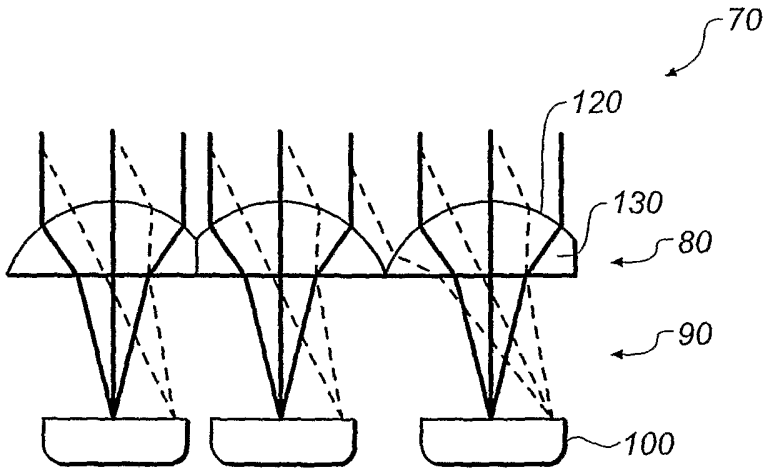

FIG. 6

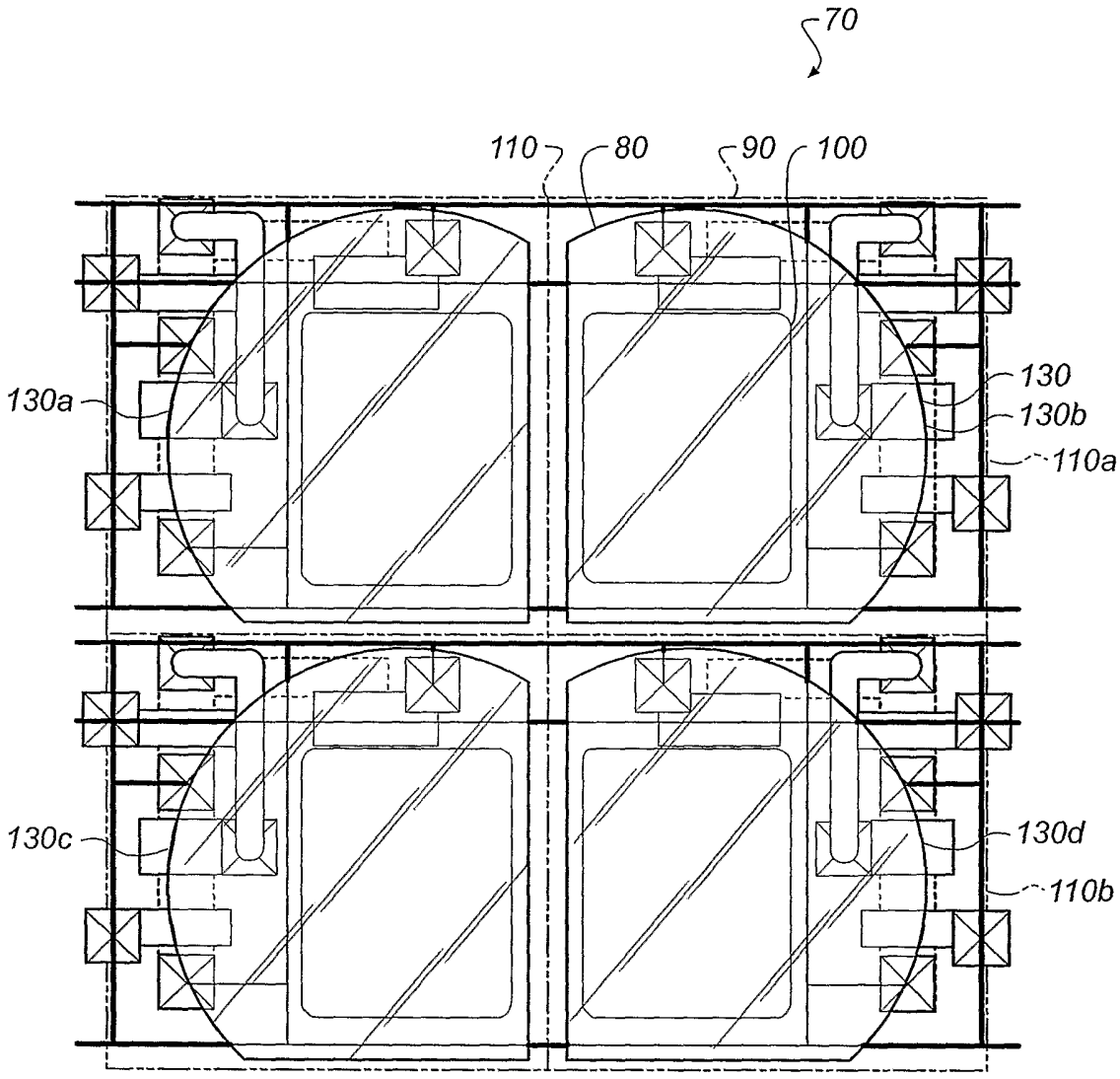

FIG. 7

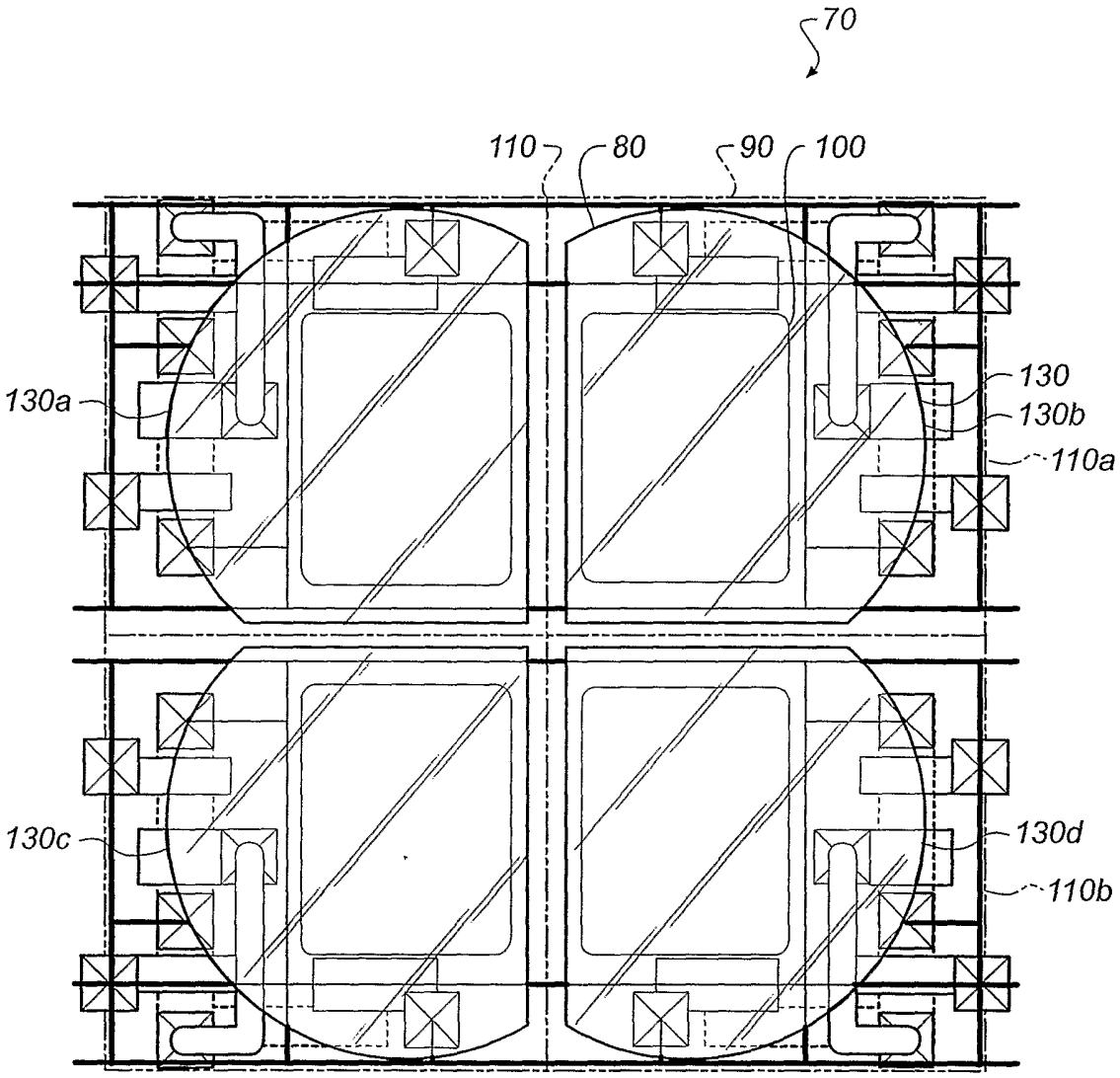

FIG. 8

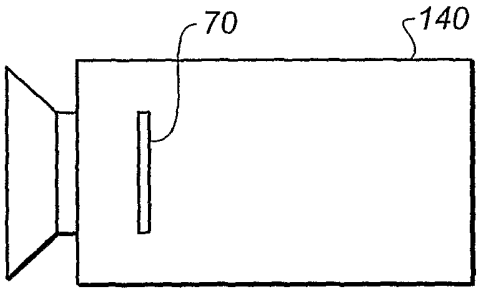

FIG. 9

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2006/020585

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01L31/0232 H01L27/146

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

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

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data, PAJ, INSPEC, COMPENDEX

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 195 45 484 A1 (DEUTSCHE TELEKOM AG, 53113 BONN, DE; DEUTSCHE TELEKOM AG) 12 June 1997 (1997-06-12)	1,9
Y	column 3, lines 56-60 column 1, lines 7-11,24-31,53-58 figure 4	2-4, 10-12
Y	US 2005/078377 A1 (LI JIN ET AL) 14 April 2005 (2005-04-14) paragraphs [0007], [0029] figures 3,4	2-4, 10-12
X	US 5 536 455 A (AOYAMA ET AL) 16 July 1996 (1996-07-16) column 6, lines 7-15,54-61; figures 7,8,11	1,9

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[X] Further documents are listed in the continuation of Box C.

[X] 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

"E" earlier document but published on or after the international filing date

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"P" document published prior to the international filing date but later than the priority date claimed

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"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
23 August 2006	29/08/2006

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Markmann, M

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2006/020585

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2003/210462 A1 (FREESE ROBERT P ET AL) 13 November 2003 (2003-11-13), paragraphs [0060] - [0062], [0064] - [0066], [0075] - [0077]; figures 10-12,16	1,9
A	WO 02/49366 A (3DV SYSTEMS, LTD; MALINOVICH, YACOV) 20 June 2002 (2002-06-20) page 9, line 27 - page 11, line 9 figures 2-4	2-4, 10-12

INTERNATIONAL SEARCH REPORT

Information on patent family members

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