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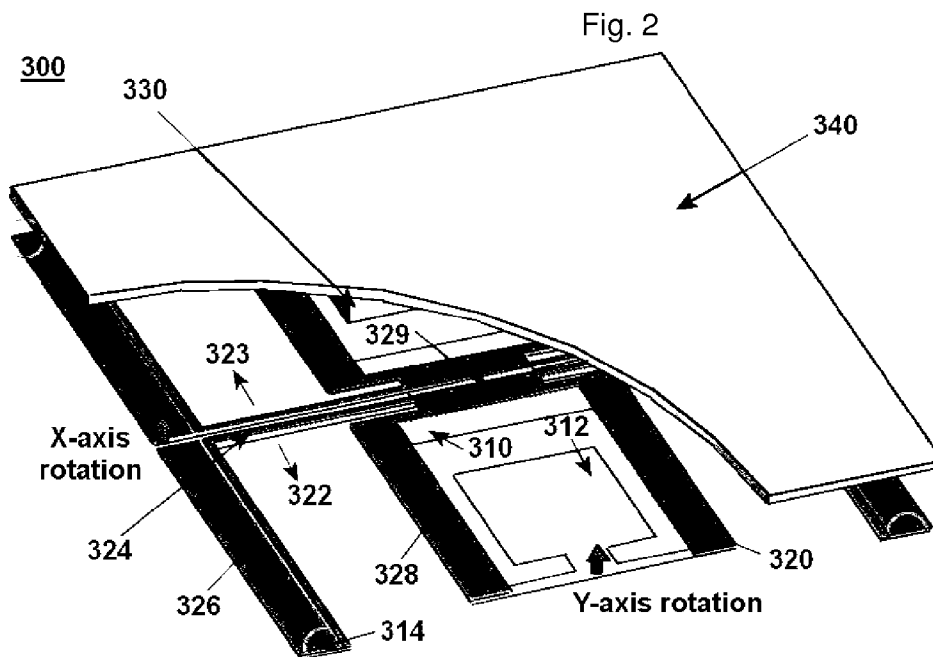
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(54) Title: AN INDEPENDENT TWO-AXIS MICRO-ELECTRO-MECHANICAL SYSTEMS MIRROR USING A PIEZOELECTRIC FORCE



(57) Abstract: The present invention relates to a micro-electro-mechanical systems (MEMS) mirror. More particularly, this invention relates to an independent two-axis MEMS mirror that can be independently actuated in a first axis direction and a second axis direction, orthogonal to each other, using a piezoelectric force, thereby significantly improving the fill-factor. The MEMS mirror can be independently actuated in a first axis direction and a second axis direction, orthogonal to each other, using a piezoelectric force, thereby significantly improving the fill-factor.

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Description

AN INDEPENDENT TWO-AXIS MICRO-ELECTRO-MECHANICAL SYSTEMS MIRROR USING A PIEZOELECTRIC FORCE

Technical Field

- [1] The present invention relates to a micro-electro-mechanical systems (MEMS) mirror. More particularly, this invention relates to an independent two-axis MEMS mirror that can be independently actuated in a first axis direction and a second axis direction, orthogonal to each other, using a piezoelectric force, thereby significantly improving the fill-factor.

Background Art

- [2] Recently, micro-electro-mechanical systems (MEMS) have been employed in various devices. This technology is comprised of a computer combined with a small mechanism, such as a sensor valve, a gear, a reflector and a semiconductor chip manipulator, etc. MEMS, also referred to as a smart meter, are a device with a microcircuit inside a small silicon chip, installed into mechanical apparatuses such as a reflector or a sensor. For example, MEMS are utilized in a variety of applications, such as a device inflating an air bag to match a passenger's weight with a vehicle's speed as detected by the air bag, a global positioning system (GPS) sensor that reads a continuous track of freight transportation, a treatment process for freight transportation, an interactive sensor for sensing changes in the air flow on the surface of airplane wings according to the air resistance and performing a corresponding operation according to the sensing result, an optical switch for outputting an optical signal at 20 nanometers per second, a sensor-manipulated heating/cooling device, and a sensor installed in a building for changing the flexibility of matter that reacts to atmospheric pressure. MEMS enhance the performance of their applications but, on the contrary, reduce the size of the products and the maintenance fees, so that they can be adapted to a variety of fields.
- [3] Such MEMS can be also adapted to a mirror. The mirror employing MEMS (hereinafter referred to as an MEMS mirror) is divided into a mirror using an electrostatic force, a mirror using an electromagnetic force, a mirror using a thermal deformation, and a mirror using a piezoelectric force, according to a method for driving a mirror. In particular, the mirror using an electrostatic force is further divided according to whether it is driven by a parallel-plate drive method or a comb-drive method.
- [4] Each of the driving methods illustrated above has a specific feature, in comparison with other driving methods. In particular, the driving method using a piezoelectric

force, which will be described in the present invention, is advantageous in that: (1) a relatively large displacement can be achieved by a low driving voltage; (2) power consumption is very low; and (3) driving can be easily controlled due to the linear relationship between the displacement and voltage, in comparison with other driving methods. However, there have been few known cases where a driving method using a piezoelectric force has been applied to an MEMS mirror. Although such a case exists, the driving method causes a very low fill-factor and thus is not suitable for an MEMS mirror array. In particular, there are not any known examples where a two-axis MEMS mirror is tilted in the orthogonal directions by using a piezoelectric force. Therefore, a new MEMS mirror is required which can cause a high fill-factor suitable for the implementation of an MEMS mirror array and can be actuated independently in the two axes using a piezoelectric force.

Disclosure of Invention

Technical Problem

- [5] The present invention solves the above problems, and provides an independent two-axis micro-electro-mechanical systems mirror that can be independently actuated in a first axis direction and a second axis direction, orthogonal to each other, using a piezoelectric force, thereby significantly improving the fill-factor.

Technical Solution

- [6] In accordance with an exemplary embodiment of the present invention, the present invention provides an independent two-axis micro-electro-mechanical systems (MEMS) mirror using a piezoelectric force including: a base plate; silicon layers formed on the base plate; piezoelectric actuating part layers for tilting the MEMS mirror with respect to a first axis and a second axis, which are orthogonal to each other, the piezoelectric actuating part layers including a piezoelectric material, being formed on the silicon layers, and including a first symmetric part and a second symmetric part, which are symmetrically formed and separated from each other; a pair of mirror pedestals disposed in the first symmetric part and the second symmetric part, respectively, on the silicon layers; and a mirror plate mounted onto the pair of mirror pedestals. Here, the first symmetric part and the second symmetric part each include: a first piezoelectric actuating part formed as a first shape (
 □
) including a rotation axis close to and across the center portion of the mirror plate; and a second piezoelectric actuating part formed as a second shape (
 □
) wrapping the mirror pedestal within the first shape (
 □

) of the first piezoelectric actuating part. Also, the silicon layers and the piezoelectric actuating part layers include: fixed parts, serving as a fixed axis of rotation of the MEMS mirror with respect to the first axis, which are fixed to the base plate by both ends of the first shape (

□

) of the first piezoelectric actuating part. In addition, the second piezoelectric actuating part includes a coupling point, serving as a fixed axis of rotation of the MEMS mirror with respect to the second axis, which is coupled by a center portion of the second shape (

□

) and the rotation axis.

- [7] Preferably, the piezoelectric actuating part layers each include an upper electrode, a piezoelectric material, and a lower electrode in that order.

Advantageous Effects

- [8] As described above, the independent two-axis micro-electro-mechanical systems mirror, according to the present invention, can be independently actuated in a first axis direction and a second axis direction, orthogonal to each other, using a piezoelectric force, thereby significantly improving the fill-factor.

Brief Description of the Drawings

- [9] The features and advantages of the present invention will be more apparent from the following detailed description in conjunction with the accompanying drawings, in which:

- [10] Figure 1 is a view that explains an operating principle of a piezoelectric actuator; and

- [11] Figure 2 is a view illustrating an independent two-axis micro-electro-mechanical systems mirror using a piezoelectric force according to an embodiment of the present invention.

[12]

[13] <Brief Description of Symbols in the Drawings>

[14] 210: fixed part

[15] 220: upper electrode

[16] 230: piezoelectric material

[17] 240: lower electrode

[18] 250: base plate

[19] 300: MEMS mirror using a piezoelectric force (according to an embodiment of the present invention)

[20] 310: silicon layer

- [21] 312: portion for mirror pedestal
- [22] 314: fixed part
- [23] 320: piezoelectric actuating part layer
- [24] 322: first symmetric part
- [25] 323: second symmetric part
- [26] 324: rotation axis
- [27] 326: first piezoelectric actuating part
- [28] 328: second piezoelectric actuating part
- [29] 329: coupling point of rotation with respect to the Y-axis
- [30] 330: mirror pedestal
- [31] 340: mirror plate

Best Mode for Carrying Out the Invention

- [32] Now, preferred embodiments of the present invention will be described in detail with reference to the accompanying drawings.
- [33] Figure 1 is a view that explains an operating principle of a piezoelectric actuator. The piezoelectric actuator is fixed to a fixed part 210, and includes an upper electrode 220, a piezoelectric material 230, a lower electrode 240, and a base plate 250 in order. The piezoelectric actuator operates in such a way that: when voltage is applied to the upper and lower electrodes 220 and 240, the piezoelectric material 230 therebetween shrinks and accordingly the piezoelectric actuator undergoes an upward rotational displacement with respect to the fixed part 210 as illustrated by an arrow in Figure 1. When a mirror plate is mounted onto the upper electrode 220 of the piezoelectric actuator and the piezoelectric actuator is operated, it is lifted up by the upward rotational displacement. The present invention is implemented by applying the operating principle of the piezoelectric actuator to an MEMS mirror.
- [34] Figure 2 is a view illustrating an independent two-axis MEMS mirror using a piezoelectric force according to an embodiment of the present invention. As shown in Figure 2, the MEMS mirror 300 is configured in such a way that: silicon layers 310 are formed at both sides on a base plate (not shown); piezoelectric actuating part layers 320 including a piezoelectric material are formed on the silicon layers 310 and are independently actuated with respect to the x-axis and y-axis; a pair of mirror pedestals 330 are disposed at symmetrical positions on the silicon layers 310; and a mirror plate 340 is mounted onto the pair of mirror pedestals 330.
- [35] The piezoelectric actuating part layer 320 and mirror pedestal 330 are mounted on the silicon layer 310. As shown in Figure 2, the four points of the fixed part 314, which are, correspondingly and respectively, close to the vertexes of the rectangular MEMS mirror 300, and the piezoelectric actuating part layer 320 are fixed to the base

plate. The fixed part 314 serves as a fixed point when a first piezoelectric actuating part 326 of the piezoelectric actuating part layer 320 is displaced by a piezoelectric force. Also, the silicon layer 310 further includes a portion 312 in which a pair of mirror pedestals 330 are formed, so that the pair of mirror pedestals 330 do not directly contact the base plate. That is, the pair of mirror pedestals 330 are mounted on the silicon layer 310, which is fixed to the base plate by only the four points of the fixed parts 314, and thus floated with respect to the base plate. Therefore, the mirror plate 340 can be tilted free from the base plate.

[36] The piezoelectric actuating part layer 320 is configured to include a first symmetric part 322 and second symmetric part 323 which are symmetrically shaped and separated from each other. The first and second symmetric parts 322 and 323 are each configured in such a way that: a rotation axis 324 is close to and across the center portion of the mirror plate 340; a first piezoelectric actuating part 326 is formed as a first shape (

□

) by the rotation axis 324 and the fixed part 314 and allows the MEMS mirror to tilt with respect to a first axis, in which the fixed part 314 serves as a fixed point of rotation with respect to the first axis; and a second piezoelectric actuating part 328 is formed as a second shape (

□

) wrapping the mirror pedestal 330 within the first shape (

□

) of the first piezoelectric actuating part 326, and includes a coupling point 329 that couples the center side of the second shape (

□

) to the rotation axis 324, so that the MEMS mirror can be tilted with respect to a second axis, in which the coupling point 329 serves as a fixed axis of rotation with respect to the second axis.

[37] The mirror pedestals 330 are placed at the portions 312 on the silicon layers 310, i.e., at the symmetrical locations of the first and second symmetric parts 322 and 323. The mirror pedestals 330 serve as columns supporting the mirror plate 340.

[38] The mirror plate 340 mounted on the mirror pedestals 330 is tilted in such a way that one of the four directions, front, rear, left and right, is pushed and lifted up by a driving force generated by the piezoelectric actuating part layer 320. When the front and rear portions of the mirror plate 340 are pushed and lifted up, the mirror plate 340 is tilted with respect to the Y-axis. On the contrary, when the left and right portions are pushed and lifted up, the mirror plate 340 is tilted with respect to the X-axis.

[39] Referring to Figure 2, the operating principle of the MEMS mirror 300 will be described in detail as follows.

- [40] Regarding the operating principle with respect to the X-axis: When a voltage is applied to the left sides of the first shapes (
 □
) of the first and second symmetric parts 322 and 323, respectively, the first piezoelectric actuating part 326 causes an upward rotation displacement with respect to the fixed part 314 as a fixed axis (see the X-axis rotation indicated by a red arrow in Figure 2). Therefore, a driving force is generated to lift up the left side of the mirror, i.e., the mirror is rotated clockwise with respect to the X-axis. Similarly, when a voltage is applied to the right sides of the first shapes (
 □
) of the first and second symmetric parts 322 and 323, respectively, a driving force is generated to lift up the right side of the mirror, i.e., the mirror is rotated counter-clockwise with respect to the X-axis.
- [41] Regarding the operating principle with respect to the Y-axis: When a voltage is applied to both sides of the second shapes (
 □
) of the first symmetric part 322, the second piezoelectric actuating part 328 causes an upward rotation displacement with respect to the coupling point 329 as a fixed axis (see the Y-axis rotation indicated by a red arrow in Figure 2). Therefore, a driving force is generated to push and lift up the lower side of the mirror, i.e., the mirror is rotated with respect to the Y-axis. Similarly, when a voltage is applied to both sides of the second shapes (
 □
) of the second symmetric part 323, a driving force is generated to push and lift up the upper side of the mirror with respect to the coupling point 329 as a fixed axis, and thus the mirror is rotated, with respect to the X-axis, in the opposite direction to the case where a voltage is applied to both sides of the second shapes (
 □
) of the first symmetric part 322.
- [42] The rotation with respect to the Y-axis is performed independently of the rotation with respect to the X-axis. That is, regardless of whether the first piezoelectric actuating part 326 performs a rotating operation with respect to the X-axis, the second piezoelectric actuating part 328 placed in the first piezoelectric actuating part 326 is actuated with respect to the rotation axis 324 as a fixed axis (i.e., the coupling point 329 as a part of the rotation axis 324). That is, the MEMS mirror using a piezoelectric force, according to the present invention, is configured to minimize a mechanical coupling between the X-axis rotation and Y-axis rotation.
- [43] A simulation result of an independent two-axis MEMS mirror using a piezoelectric

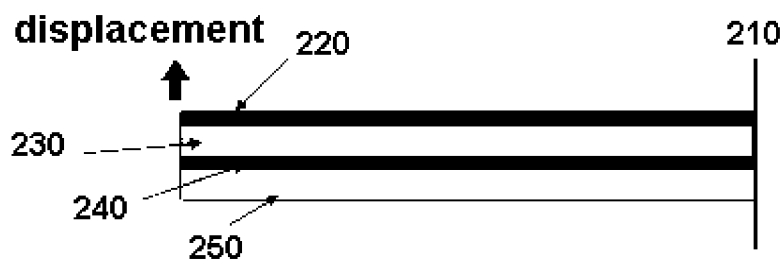
force, which is designed according to an embodiment of the present invention, is as follows. When the bias voltage is 50 V, the MEMS mirror can be tilted clockwise by 3.9 with respect to the X-axis, and the MEMS mirror can be tilted in a direction by 3.0 with respect to the Y-axis. This result indicates that even a relatively low driving voltage (50 V) can achieve a relatively large displacement: total 7.8 with respect to the X-axis (3.9×2) and total 6.0 with respect to the Y-axis (3.0×2). That is, using a piezoelectric force requires very low power consumption and makes it possible to achieve a linear relationship between voltage and displacement, which is easy to control. Therefore, the present invention can be widely used in a variety of applications.

- [44] Although the preferred embodiments of the present invention have been disclosed for illustrative purposes, those skilled in the art will appreciate that various modifications, additions and substitutions are possible, without departing from the scope and spirit of the invention as disclosed in the accompanying claims.

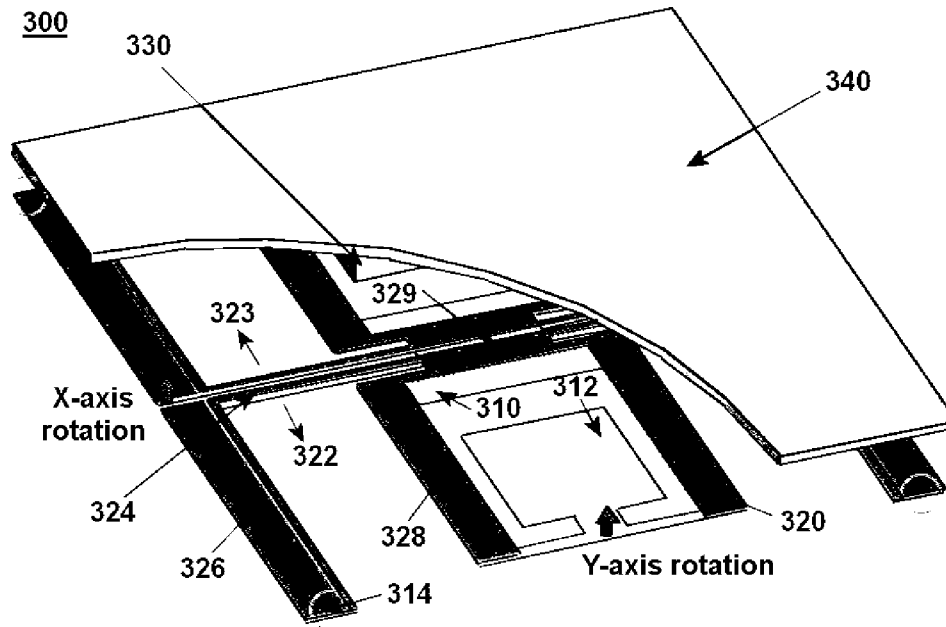
Claims

- [1] An independent two-axis micro-electro-mechanical systems (MEMS) mirror using a piezoelectric force comprising:
- a base plate;
 - silicon layers formed on the base plate;
 - piezoelectric actuating part layers for tilting the MEMS mirror with respect to a first axis and a second axis, which are orthogonal to each other, the piezoelectric actuating part layers including a piezoelectric material, being formed on the silicon layers, and including a first symmetric part and a second symmetric part, which are symmetrically formed and separated from each other;
 - a pair of mirror pedestals disposed in the first symmetric part and the second symmetric part, respectively, on the silicon layers; and
 - a mirror plate mounted onto the pair of mirror pedestals, wherein the first symmetric part and the second symmetric part each include: a first piezoelectric actuating part formed as a first shape ($\square$) including a rotation axis close to and across the center portion of the mirror plate; and a second piezoelectric actuating part formed as a second shape ($\square$) wrapping the mirror pedestal within the first shape ($\square$) of the first piezoelectric actuating part, wherein the silicon layers and the piezoelectric actuating part layers include: fixed parts, serving as a fixed axis of rotation of the MEMS mirror with respect to the first axis, which are fixed to the base plate by both ends of the first shape ($\square$) of the first piezoelectric actuating part, wherein the second piezoelectric actuating part includes a coupling point, serving as a fixed axis of rotation of the MEMS mirror with respect to the second axis, which is coupled by a center portion of the second shape ($\square$) and the rotation axis.
- [2] The MEMS mirror according to claim 1, wherein the piezoelectric actuating part layers each include an upper electrode, a piezoelectric material, and a lower electrode in that order.

[Fig. 1]



[Fig. 2]



A. CLASSIFICATION OF SUBJECT MATTER**G02B 26/08(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)

IPC 8 : G02B

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 model since 1975.

Japanese utility models and applications for utility model since 1975.

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

eKIPASS(KIPO internal)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	KR10-2002-0019628 A (LG ELECTRONICS INC.) 13 March 2002 See abstract and figs2b,3.	1-2
A	US2004/0032634 A1 (DOO-YOUNG HAH et al.) 19 February 2004 See abstract and fig1a.	1-2
A	KR10-2002-0028689 A (LG ELECTRONICS INC.) 17 April 2002 See abstract and fig2b.	1-2



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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"O" document referring to an oral disclosure, use, exhibition or other means

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"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

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INTERNATIONAL SEARCH REPORT

Information on patent family members

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None