

MOVING STRUCTURE AND LIGHT SCANNING MIRROR USING THE SAME

[DETAILED DESCRIPTION OF THE INVENTION]

[TECHNICAL FIELD]

[0001]

The present invention relates to a moving structure having a moving plate which is configured to be pivoted swingably by hinges, and a light scanning mirror using the same.

[BACKGROUND ART]

[0002]

Conventionally, it is known that some optical instruments such as bar-code readers or projectors use a light scanning mirror to scan light beams incident to a mirror by swinging a moving plate to which the mirror is provided (see patent document 1, for example). As for the light scanning mirror, a miniature one having a semiconductor moving structure formed by using micro-machining technology is known. Such a moving structure has a moving plate to which a mirror face is formed when it is used as a light scanning mirror and a stationary frame which supports the moving plate. The moving plate and the stationary frame are coupled by hinges each other. The moving plate rotates with respect to the stationary frame while twisting the hinges so as to swing around the hinges serving as the axes by applying a driving force to the moving plate. As for the driving force, electro-static force which is generated when a voltage

is applied between a pair of comb tooth electrodes facing each other and formed between the moving plate and the stationary frame, for example, a force generated by piezoelectric effect or electro-magnetic force is used, for example.

[0003]

By the way, in such a light scanning mirror, in order to generate the driving force by a small driving voltage and to assure swing angle necessary to scan light, it is sufficient to decrease a spring constant of the hinges in torsion direction by thinning the hinges. However, when thinning the hinges, the hinges become weak for a physical shock. Therefore, the hinges may be broken when a mechanical shock is applied from outside, and thus, the light scanning mirror may become immovable.

[0004]

The patent document 1 discloses a micro-mirror device in which pivots are formed to enable to support the center portion of the moving plate which serves as the center of inclination. However, the micro-mirror device has a problem of difficulty of manufacturing because the pivots are necessary to be formed at predetermined positions precisely to correspond to the center of the moving plate and to approach the moving plate.

[PARENT DOCUMENT 1] JP 2003-57575A

[DISCLOSURE OF INVENTION]

[PROBLEMS THAT THE INVENTION IS GOING TO SOLVE]

[0005]

The present invention is conceived in consideration of the above mentioned problem and purposed to provide a moving structure and a light scanning mirror using the same, which can be manufactured easily and has a high crashworthy because the hinges are nonbreakable even when a mechanical shock is applied from outside.

[MEANS TO SOLVE THE PROBLEMS]

[0006]

For achieving the above mentioned purpose, the invention of claim 1 relates to a moving structure comprising a moving plate, twin hinges constituting an axis of swing motion of the moving plate wherein an end of each hinge is connected to the moving plate, and a frame to which another end of each of the twin hinges is connected and which supports the hinges, and wherein the moving plate is configured swingable with respect to the frame while twisting the twin hinges, characterized in that stoppers are formed along the hinges at both sides of the hinges, so that a quantity of displacement of the moving plate in a direction parallel to an upper face of the moving plate is restrained by contacting a part of the moving structure when the moving plate displaces.

[0007]

The invention of claim 2 is characterized in that recesses are provided on the moving plate so that they are formed to be concaved in a longitudinal direction of the hinges in the vicinities of portions pivoted by the hinges, and the stoppers are integrally formed with the

frame and formed to be located between the hinges and side end portions of the moving plate to which the recesses are formed, in the invention of claim 1.

[0008]

The invention of claim 3 is characterized in that the moving plate has contacting protrusions formed to protrude toward the stationary frame respectively at positions distant from the hinges than the stoppers at both side portions of the hinges, in the invention of claim 1.

[0009]

The invention of claim 4 is characterized in that a chamfer of a round shape is formed at each corner of the stoppers, in the invention of one of claim 1 to claim 3.

[0010]

The invention of claim 5 is characterized in that the stoppers are configured to be the same electric potential as the hinges, in the invention of one of claim 1 to claim 7.

[0011]

The invention of claim 6 is characterized in that a sticking prevention film or a protrusion is formed on at least a part of each of the stopper so as not to occur sticking between the stopper and one which contacts the stopper, in the invention of one of claim 1 to claim 5.

[0012]

The invention of claim 7 is characterized in that a mirror face

for reflecting incident light is provided on a top face of the moving plate of the moving structure in one of claim 1 to claim 6.

[EFFECTS OF THE INVENTION]

[0013]

According to the invention of claim 1, a quantity of the displacement of the moving plate in a lateral direction is restrained by contacting the stopper to a part of the moving structure, even when the moving plate is displaced in the lateral direction by applying an impact from outside, for example. Therefore, the moving plate does not displace so much, and breakage of the hinge is prevented, so that crashworthy of the moving structure can be enhanced. Since the stoppers are disposed in the vicinities of the hinges, it is possible to restrain the displacement of the moving plate in the lateral direction effectively, even when the moving plate is inclined with respect to the frame. In addition, since level of precision required to locations and shapes of the stoppers is lower in comparison with the conventional case of forming a pivot shaped protrusion, the moving structure can be manufactured relatively easier. Moreover, since the stoppers may not contact the hinges, it is possible to prevent the breakage of the hinges surely.

[0014]

According to the invention of claim 2, since the stoppers can be formed easily by processing a member which constitutes the moving plate or the frame when forming the moving plate or the frame, the moving structure can be manufactured much easier.

[0015]

According to the invention of claim 3, the quantity of the displacement of the moving plate can be restrained by contacting the stopper with a side of the recess in the displacement of the moving plate. Therefore, it is possible to configure a structure to restrain the quantity of the displacement of the moving plate much easier and stronger.

[0016]

According to the invention of claim 4, since there is no aculeate shape at a portion of each of the stoppers which contacts another portion of the moving structure in the displacement of the moving plate, stress rarely concentrates to the stopper and the portion contacting with the stopper when the portion contact. Therefore, it is possible to prevent the breakage of the stopper or the portion of the moving structure contacting the stopper.

[0017]

According to the invention of claim 5, even when the stopper contacts another portion of the moving structure due to the displacement of the moving plate in a lateral direction, it is possible to prevent that the moving plate becomes immovable to swing due to occurrence of sticking by electrostatic force.

[0018]

According to the invention of claim 6, even when the stopper contacts another portion of the moving structure due to the displacement of the moving plate in a lateral direction, it is possible

to prevent that the moving plate becomes immovable to swing because occurrence of sticking is prevented by the sticking prevention film or the protrusion.

[0019]

According to the invention of claim 7, it is possible to enhance the crashworthy of the light scanning mirror and to manufacture the light scanning mirror easily.

[BEST MODE FOR CARRYING OUT THE INVENTION]

[0020]

A first embodiment of the present invention is described below with reference to figures. FIGS. 1(a) and (b), FIG. 2 and FIG. 3 show an example of a light scanning mirror (a moving structure) in accordance with this embodiment. The light scanning mirror 1 is a miniature one which is to be mounted on an optical instrument such as a bar-code reader, a projector apparatus which projects an image on an external screen, or a light switch, and has a function to scan light beams which are incident from external light source or the like (not shown in the figures).

[0021]

First, a configuration of the light scanning mirror 1 is described. The light scanning mirror 1 is a MEMS (Micro Electro Mechanical System) device manufactured by processing a SOI (Silicon on Insulator) substrate 200 using so-called micro machining technology. The SOI substrate 200 is a triple-layered substrate consisting of a first silicon layer (activation layer) 200a and a second

silicon layer (substrate layer) 200b which are joined via a silicon oxidation film (BOX (Buried Oxide) layer) 220. Since the oxidation film 220 has electric insulation characteristic, the first silicon layer 200a and the second silicon layer 200b are electrically insulated each other. A thickness of the first silicon layer 200a is about 30 μ m, and a thickness of the second silicon layer 200b is about 400 μ m. As shown in FIG. 1(a), the light scanning mirror 1 is a rectangular solid device that a top face thereof is substantially square or substantially rectangular of about several mm in planar view.

[0022]

The light scanning mirror 1 comprises a moving plate 2 having substantially a rectangular shape in planar view and a mirror face 10 formed on a top face thereof, twin hinges 3 which are respectively connected to both end portions of the moving plate 2 at an end of each and constitute an axis of swing motion of the moving plate 2, a stationary frame (frame) 4 disposed to surround peripheries of the moving plate 2 and to support other end portions of the hinges 3, comb tooth electrodes 5 having electrodes 2a at a part of the moving plate 2 and electrodes 4a at a part of the stationary frame 4, and stoppers 6 formed on the stationary frame 4. As shown in FIG. 1(b), a space is formed below the moving plate 2, and the moving plate 2 is supported through the hinges 3 to be swingable with respect to the stationary frame 4 around the hinges 3 serving as the axis of swing motion while twisting the twin hinges 3. The twin hinges 3 are formed so that an axis formed by them passes through a center of

gravity of the moving plate 2 in planar view. A width dimension of the hinges 3 is about several μm to several tens μm , for example.

Voltage application areas such as metal films 10a and 10b are formed on a top face of the stationary frame 4. Besides, the shapes of the moving plate 2 and the mirror face 10 are not limited to a rectangle, and, they may be a circle or an oval, for example. The light scanning mirror 1 is mounted on a circuit board B or the like so that a glass substrate 110 is joined to a bottom face of the stationary frame 4, for example.

[0023]

As shown in FIG. 3, the moving plate 2 and the hinges 3 are formed on the first silicon layer 200a. The mirror face 10 is a thin film made of aluminum, for example, and formed to reflect light beams incident to the top face of the moving plate 2 from outside. The moving plate 2 is formed substantially symmetrical shape with respect to a plane perpendicular to the moving plate 2 and passing through the hinges 3, and configured to swing smoothly around the hinges 3.

[0024]

The stationary frame 4 is configured of the first silicon layer 200a, the oxidation film 220 and the second silicon layer 200b. In this embodiment, trenches 101 are formed on the stationary frame 4 so as to divide the first silicon layer 200a into three regions which are electrically insulated each other, for example. The trenches 101 are spaces formed to be channel shapes communicating top end to bottom

end of the first silicon layer 200a to reach the oxidation film 220. Since the trenches 101 are formed only on the first silicon layer 200a, entire of the stationary frame 4 is formed integrally. The trenches 101 are formed at four places so that two supporting portions 4b respectively connected to the twin hinges 3 are electrically insulated from other portions of the stationary frame 4. The stationary frame 4 is divided into the two supporting portions 4b which are connected to the twin hinges 3 to be the same electric potential as that of the moving plate 2 and two portions on which the voltage application areas 10b are formed on the top face thereof by forming the trenches 101. Since the trenches 101 separate the first silicon layer 200a, these portions are electrically insulated each other. In other words, as shown by adding patterns to respective portions in FIG. 2, the moving plate 2, the hinges 3 and the stationary frame 4 are configured as three portions electrically insulated each other.

[0025]

The electrodes 2a of the comb tooth electrodes 5 are formed in side end portions of the moving plate 2 serving as free ends where the hinges 3 are not connected, and the electrodes 4a are formed in portions of the stationary frame 4 facing the side end portions of the moving plate 2. The electrodes 2a and 4a constituting the comb tooth electrodes 5 are formed to engage with each other. Gaps between the electrodes 2a and 4a are about 2 μ m to 5 μ m.

[0026]

The stoppers 6 are provided to restrain a quantity of

displacement in a lateral direction of the moving plate 2, that is, in a direction substantially perpendicular to the axis of swing motion configured by the hinges 3 and substantially in parallel with the top face of the SOI substrate 200. As shown in FIG. 2, the stoppers 6 are formed integrally with the stationary frame 4 on the first silicon layer 200a and to protrude toward the moving plate 2 from the stationary frame 4 and along the hinges 3 at both sides of the hinges 3. In this embodiment, recesses 2e are formed in regions of the moving plate 2 where the hinges 3 are connected so as to hollow in a direction to depart from the stationary frame 4, that is, a longitudinal direction of the hinges 3. In other words, the hinges 3 are connected to inner end portions of the recesses 2e formed on the moving plate 2. The stoppers 6 are formed so that front ends of them near to the moving plate 2 are located between the hinges 3 and the side end portions of the moving plate 2 forming the recesses 2e. The stoppers 6 are formed to have predetermined gaps between the hinges 3 and them so as not to block the swing motion of the moving plate 2 in a normal state where no mechanical shock is applied to the light scanning mirror 1 from outside. Therefore, the hinges 3 is never broken by contacting the stoppers 6. The stoppers 6 are configured to protrude from the supporting portions 4b of the stationary frame 4 where the hinges 3 are connected, and thus, the moving plate 2, the hinges 3 and the stoppers 6 are configured to be the same electric potential.

[0027]

As shown in FIG. 2, chamfers 6a formed to be round shape are

provided at corners in the vicinity of the front ends of the stoppers 6. In addition, chamfers 2f formed to be round shape are provided at corners of the recesses 2e facing the stoppers 6. The stoppers 6 are formed so that gaps between the stoppers 6 and the recesses 2e of the moving plate 2 become narrower than gaps between the stoppers 6 and the hinges 3. In addition, sticking prevention films (not illustrated in the figures) are formed on portions of the stoppers 6 facing the moving plate 2. The sticking prevention films are provided by forming DLC (Diamond Like carbon) film or SAM (Self-assembled Monolayer) on the portions of the stoppers 6 facing the moving plate 2, for example.

[0028]

Subsequently, motion of the light scanning mirror 1 which is configured as above is described. The moving plate 2 of the light scanning mirror 1 is driven when the comb tooth electrodes 5 generate driving forces at predetermined driving frequency. The comb tooth electrodes 5 are driven by applying voltages having a predetermined driving frequency between the electrodes 2a and 4a with periodically varying the electric potential of the voltage application area 10a which will be the same electric potential as that of the electrodes 4a under a state that the voltage application area 10a disposed in the supporting portion 4b is connected to the ground electric potential and the electrodes 2a of the moving plate 2 is at a reference electric potential, for example. Two sets of the electrodes 2a provided in both end portions of the moving plate 2 are simultaneously gravitated

to the electrodes 4a facing thereto by electrostatic force by varying the electric potentials of two sets of the electrodes 4a of the comb tooth electrodes 5 to predetermined driving electric potential (for example, several tens volts), simultaneously. In this light scanning mirror 1, it is configured that pulse voltages of rectangular waveforms, for example, are applied to the comb tooth electrodes 5, and the driving forces by the comb tooth electrodes 5 are periodically generated.

[0029]

In this embodiment, the light scanning mirror 1 is configured to swing the moving plate 2 by electrostatic force as the driving force, for example. When the voltages are applied between the electrodes 2a and 4a periodically, electrostatic forces which act in directions to gravitate each other are generated between both of the electrodes 2a and 4a, and thus, the electrostatic forces act on the free ends of the moving plate 2 in directions substantially perpendicular to the top face of the moving plate 2. In other words, a torque around the hinges 3 is generated in the moving plate 2 by the electrostatic forces, when driving voltages are applied to the comb tooth electrodes 5 from outside by varying the electric potentials of the voltage application areas 10a and 10b.

[0030]

In such light scanning mirror 1, the moving plate 2 does not take level posture and inclines a little in a state of rest due to occurrence of internal stresses or the like at the time of forming in

many cases, generally. Therefore, when the comb tooth electrodes 5 are driven from the state of rest, the driving forces act on the moving plate 2 in the direction substantially perpendicular to it, and thus, the moving plate 2 rotates around the hinges 3 serving as the rotation axis. Subsequently, when the posture of the moving plate 2 becomes in a state that the electrodes 2a and the electrodes 4a completely overlap each other in side view, the driving forces of the comb tooth electrodes 5 are released, so that the moving plate 2 continues to rotate while twisting the hinges 3 by inertia force thereof. When the inertia force of the moving plate 2 in a rotational direction becomes equal to the restitution forces of the hinges 3, the rotation of the moving plate 2 in the direction stops. At this time, the comb tooth electrodes 5 are driven again, and the moving plate 2 starts to rotate in the opposite direction by the restitution forces of the hinges 3 and the driving forces of the comb tooth electrodes 5. The moving plate 2 is swung by repeating such rotations due to the driving forces of the comb tooth electrodes 5 and the restitution forces of the hinges 3. The comb tooth electrodes 5 are driven by applying the voltages having a frequency about two times as large as a resonance frequency of a vibration system configured of the moving plate 2 and the hinges 3, and the moving plate 2 is configured to be driven with resonance phenomenon so as to enlarge the swing angle thereof. Besides, since application manner and frequency of the voltages to the comb tooth electrodes 5 are not limited to the above mentioned cases, it may be configured that the driving voltages are applied as sinusoidal wave

forms, or it may be configured that the electric potentials of the electrodes 2a and 4a are varied in opposite phases each other.

[0031]

Hereupon, the light scanning mirror 1 has high crashworthy because the stoppers 6 are provided in comparison with the case that no stopper 6 is provided. FIGS. 4(a) and (b) respectively show a region of the light scanning mirror 1 in the vicinity of the stoppers 6. In a normal state where no mechanical shock or the like is applied from outside, the hinges 3 are rarely bent and it is in a state that gaps are formed between the stoppers 6 and the moving plate 2, as shown in FIG. 4(a). At this time, when vibrations or a mechanical shock are/is applied to the light scanning mirror 1 from outside, the moving plate 2 may displace in lateral direction (shown by black arrow in the figure) from the normal state while deforming the hinge 3, as shown in FIG. 4(b). When a quantity of the displacement becomes much larger, the stopper 6 contacts the side end portion of the recess 2e, so that the displacement of the moving plate 2 in the direction is restrained, and thus, quantities of deformations of the hinges 3 may not be increased no more. In addition, the hinges 3 do not contact the stoppers 6 while the moving plate 2 displaces from the normal state to a time when the stopper 6 contacts the side end portion of the recess 2e.

[0032]

In addition, the light scanning mirror is manufactured by processes as follows, for example. First, a SOI substrate 200 is

formed by forming an oxidation film 220 on a first silicon layer 200a and attaching a second silicon layer 200b thereon. Subsequently, shapes which will be the moving plate 2, the hinges 3, the stationary frame 4, the comb shaped electrodes 5 and the stoppers 6 are formed on the first silicon layer 200a side of the SOI substrate 200 by so-called bulk micro machining technology such as photolithography, or etching (first process). In this way, each portion of the light scanning mirror 1 including minute shape can be formed easily by using the bulk micro machining technology. Subsequently, a metal film is formed on a top face of the first silicon layer 200a of the SOI substrate 200 using sputtering method or the like. A mirror face 10 is formed on the moving plate 2 and voltage application areas 10a and 10b are formed on a top face of the stationary frame 4 by patterning this metal film.

[0033]

Subsequently, a shape which will be the stationary frame 4 is formed on the second silicon layer 220b by processing of the the bulk micro machining technology, similarly (second process). Etching of the oxidation film 220 is performed after processing the first silicon layer 200a and the second silicon layer 200b. Regions of the oxidation film 220 other than the stationary frame 4 are removed by performing the etching process from below the light scanning mirror 1, for example (third process). Thereby, the moving plate 2 becomes a swingable state with respect to the stationary frame 4 by being pivoted on the stationary frame 4 through the hinges 3. A plurality

of the light scanning mirrors 1 are formed on the SOI substrate 200 by passing the above mentioned first process to third process. After the third process, a plurality of the light scanning mirrors 1 formed on the SOI substrate is individually cut out. By these series of processes, a plurality of the light scanning mirrors 1 are manufactured simultaneously, so that it is possible to decrease the manufacturing cost of the light scanning mirrors 1. Besides, the manufacturing processes of the light scanning mirror 1 are not limited to these, and it is possible to be formed by laser process, ultrasonic wave process or the like, and it may be formed one by one. In addition, the processing of the second silicon layer 200b may be performed prior to the processing of the first silicon layer 200a.

[0034]

As mentioned above, since the moving plate 2 displaces not so large, and thus, breakage of the hinges 3 can be prevented by providing the stoppers 6 in this embodiment, it is possible to enhance crashworthy of the light scanning mirror 1. Since the stoppers 6 are disposed in the vicinities of the hinges 3, even when the moving plate 2 inclines with respect to the stationary frame 4, it is possible to restrain the displacement of the moving plate 2 in the lateral direction effectively, and to prevent the breakages of the hinges 3 surely. At this time, since the stoppers 6 do not contact the hinges 3, it is possible to prevent the breakage of the hinges 3 surely. In addition, since the moving plate 2 is pivoted by the hinges 3, it is hard to displace in a longitudinal direction of the axis of swing motion

configured by the hinges 3. Therefore, a quantity of the displacement of the moving plate 2 in an in-plane direction in parallel with the top face of the SOI substrate 200 can be restrained substantially completely by providing the stoppers 6, and thus, it is possible to prevent the breakage of the hinges 3 effectively. In addition, since the stoppers 6 are supported by the recesses 2e in the displacement of the moving plate 2, it is possible to constitute a strong structure for supporting the stoppers 6 easily. Still furthermore, the chamfers 6a are formed on the stoppers 6 so that the portions which may contact the side end portions of the recesses 2e are not aculeate, and similarly, the chamfers 2f are formed at side end portions of the recesses 2e so that the portions which may contact the stoppers 6 are not aculeate. Therefore, it is hard to concentrate the stress to the contacting portions of the stopper 6 and the side end portion of the recess 2e, so that it is possible to prevent breakage of the stoppers 6 and the moving plate 2.

[0035]

Furthermore, the stoppers 6 and the side end portions of the recesses 2e are at the same electric potential, and the sticking prevention films are formed on the portions of the stoppers 6 which may contact the side end portions of the recesses 2e. Therefore, even when the stopper 6 contacts the recess 2e, sticking due to electrostatic force hardly occurs, and thus, it is possible to prevent that the moving plate 2 becomes immovable, surely. Still furthermore, it is sufficient that the stoppers 6 are provided at sides of

the hinges 3 not to block the swing motion of the moving plate 2 but to contact the recesses 2e of the moving plate 2 when the moving plate 2 displaces in the lateral direction, so that positioning of the stoppers 6 is not performed accurately, and thus, the light scanning mirror 1 can be manufactured relatively easier. In particular, since the stoppers 6 can be formed simultaneously in the processes to form the stationary frame 4 by processing the first silicon layer 200a in this embodiment, proper gaps between the stoppers 6 and the stationary frame 4 can be assured and it is easily manufactured.

[0036]

Subsequently, a second embodiment of the present invention is described. FIG. 5 shows a light scanning mirror 21 in accordance with the second embodiment. Hereinafter, elements similar to those in the above mentioned first embodiment are designated by the same reference marks, and only the portions different from the above first embodiment are described. The light scanning mirror 21 has a moving plate 22 of a different shape from the moving plate 2 of the light scanning mirror 1. In other words, as shown in the figure, the moving plate 22 has no recess 2e but has contacting protrusions 22e formed to protrude toward the stationary frame 4 respectively at positions distant much farther from the hinges 3 than the stoppers 6 at both side portions of the hinges 3. Other configurations of the moving plate 22 and a configuration of the light scanning mirror 21 other than the moving plate 22 are similar to those of the light scanning mirror 1 in the first embodiment. This light scanning

mirror 21 can be manufactured easily by forming the shapes including the contacting protrusions 22e on the first silicon layer 200a by processing the bulk micro machining technology.

[0037]

FIGS. 6(a) and (b) respectively show a region of the light scanning mirror 21 in the vicinity of the stoppers 6. The two contacting protrusions 22e are respectively disposed at positions nearer to the sides of the stoppers 6 near to the hinges 3 than the contacting protrusions 22e. As shown in FIG. 6(a), it is configured that gaps between the stoppers 6 and the contacting protrusions 22e are a little narrower than gaps between the stoppers 6 and the hinges 3 in the normal state. In addition, chamfers 22f of round shape are formed at corners of the contacting protrusions 22e at the sides of the stoppers 6. When the moving plate 2 displaces in a lateral direction as shown in FIG. 6(b), one of the stoppers 6 contacts the contacting protrusion 22e, so that the moving plate 22 displaces no more. Therefore, it is possible to prevent the breakages of the hinges 3 and to enhance the crashworthy of the light scanning mirror 21 in this embodiment similar to the above mentioned first embodiment. Since the stoppers 6 do not contact the hinges 3, it is possible to prevent the breakage of the hinges 3 surely. Since the stoppers 6 and the contacting protrusions 22e are at the same electric potential, even when the stopper 6 contacts the contacting protrusion 22e, sticking hardly occurs, and thus, it is possible to maintain the light scanning mirror 21 in movable state surely.

[0038]

FIG. 7 shows a light scanning mirror 41 in accordance with a third embodiment of the present invention. The light scanning mirror 41 comprises a moving plate 42 having stoppers 46 formed along the hinges 3 replacing with the moving plate 2 of the light scanning mirror 1. In addition, contacting protrusions 44e are formed at the supporting portions 4b of the stationary frame 4. The contacting protrusions 44e are respectively formed to protrude toward the moving plate 42 at positions at both sides of the hinges 3 and distant farther from the hinges 3 than the stoppers 46. The configurations of the light scanning mirror 42 other than the moving plate 42 and the contacting protrusions 44e are similar to those of the light scanning mirror 1 in the first embodiment. This light scanning mirror 41 can be manufactured easily by forming the shapes including the moving plate 42 and the contacting protrusions 44e on the first silicon layer 200a by processing the bulk micro machining technology.

[0039]

FIGS. 8(a) and (b) respectively show a region of the light scanning mirror 41 in the vicinity of the stoppers 46. Two of the contact protrusions 44e are respectively disposed at positions near to the sides of the stoppers 46 nearer to the hinges than the contacting protrusions 44e. As shown in FIG. 6(a), it is configured that gaps between the stoppers 46 and the contacting protrusions 44e are a little narrower than gaps between the stoppers 46 and the hinges 3 in the

normal state. Chamfers 44f and chamfers 46a are formed on the contacting protrusions 44e and the stoppers 46 respectively, similar to the chamfers 2f for the recesses 2e and the chamfers 6a of the stoppers 6 of the light scanning mirror 1. As shown in FIG. 6(b), when the moving plate 42 displaces in a lateral direction, one of the stoppers 46 contacts the contacting protrusion 44e, so that the moving plate 42 displaces no more. Therefore, it is possible to prevent the breakages of the hinges 3 and to enhance the crashworthy of the light scanning mirror 41 in this embodiment similar to the above mentioned first embodiment or the second embodiment. Since the stoppers 46 do not contact the hinges 3, it is possible to prevent the breakage of the hinges 3 surely. Still furthermore, since the chamfers 44f are formed on the contacting protrusions 44e and the chamfers 46a are formed on the stoppers 46, it is possible to prevent the breakage of the stoppers 46 or the contacting protrusions 44e.

[0040]

FIG. 9 shows a region of a light scanning mirror in the vicinity of the stoppers 56 in accordance with a fourth embodiment of the present invention. In the fourth embodiment, entire configuration of the light scanning mirror is similar to that of the light scanning mirror 1 in the first embodiment, so that description of it is omitted. In the fourth embodiment, the stoppers 56 to which convexities 56c are formed are provided replacing with the stoppers 6 to which the sticking prevention films are formed. As shown in the figure, the convexities 56c are provided to form saw tooth at positions of the

stoppers 56 contacting to side end portions of the recesses 2e when the moving plate 2 displaces in planar view, for example.

[0041]

In the fourth embodiment, since the convexities 56c are provided on the stoppers 56, when the stopper 56 and the side end portion of the recess 2e contact, contacting areas of each other become smaller. Thereby, affection of electrostatic forces between the stopper 56 and the recess 2e becomes smaller, so that occurrence of sticking can be prevented. In addition, shapes of the convexities 56c are not limited to the saw tooth shapes. The convexities 56c are preferably formed to have shapes not to concentrate stress to contacting portions too much when the stopper 56 contacts the recess 2e. Still furthermore, it is preferable to form sticking prevention films at positions of the stoppers 56 contacting the side end portions of the recesses 2e in the fourth embodiment, so that occurrence of sticking can be prevented surely.

[0042]

In addition, the present invention is not limited to the configurations of the above mentioned embodiments, it is possible to modify in various manner in the scope not to change the purpose of the invention. The light scanning mirror is not limited to one which can swing around a single axis as described in the above mentioned embodiments, but it may be a biaxial gimbals type having a moving frame (frame) swingably pivoted on a stationary frame, and a mirror to which a mirror face is formed is swingably pivoted on the moving

frame, for example. In this case, displacement of a moving plate including the moving frame and the mirror can be restrained by forming stoppers along hinges by which the moving frame is pivoted. Similarly, displacement of the mirror serving as the moving plate with respect to the moving frame can be restrained by forming stoppers along hinges by which the mirror is pivoted. Furthermore, the light scanning mirror may be configured of a single silicon substrate or a metal plate instead of the SOI substrate, and driving forces to swing the moving plate may be electrostatic forces acting between flat electrodes, electromagnetic forces, electrostriction forces or heatstriction forces instead of the electrostatic forces acting between comb tooth electrodes. Still furthermore, the stoppers may not be formed integrally with the moving plate or the frame, and it may be disposed at positions distant from the moving plate or the frame if it enables to restrain the displacement of the moving plate. In any case, it is possible to restrain the displacement of the moving plate in the lateral direction, to prevent the breakage of the hinges and to enhance the crashworthy of the light scanning mirror by forming the stoppers along the hinges at positions in sides of the hinges which support the moving plate.

[0043]

Still furthermore, the present invention is not limited to a light scanning mirror having a mirror face to scan light, and it is widely applicable to a moving structure that a moving plate which is configured swingable with respect to a stationary frame by twin

hinges is formed on a semiconductor substrate. In other words, it is possible to enhance crashworthy of the moving structure by providing stoppers along the hinges at positions in sides of the hinges.

[BRIEF DESCRIPTION OF THE DRAWINGS]

[0044]

[FIG. 1] (a) is a perspective view showing an upper side of a light scanning mirror which is a moving structure in accordance with a first embodiment of the present invention, and (b) is a perspective view showing a lower side of the light scanning mirror.

[FIG. 2] Plain view of the above light scanning mirror

[FIG. 3] A-A sectional view in FIG. 2

[FIG. 4] (a) is a plain view showing a portion of the above light scanning mirror in the vicinity of stoppers, and (b) is a plain view showing the same part when the moving plate displaces from normal state.

[FIG. 5] Perspective view showing a light scanning mirror in accordance with a second embodiment of the present invention

[FIG. 6] (a) is a plain view showing a portion of the above light scanning mirror in the vicinity of stoppers, and (b) is a plain view showing the same part when the moving plate displaces from normal state.

[FIG. 7] Perspective view showing a light scanning mirror in accordance with a third embodiment of the present invention

[FIG. 8] (a) is a plain view showing a portion of the above light scanning mirror in the vicinity of stoppers, and FIG. 8(b) is a plain

view showing the same part when the moving plate displaces from normal state.

[FIG. 9] Plain view showing a portion of a light scanning mirror in the vicinity of stoppers in accordance with a fourth embodiment of the present invention

[LIST OF MARKS]

[0045]

- 1, 21, 41 light scanning mirror (moving structure)
- 2, 22, 42 moving plate
- 2e recess
- 3 hinges
- 4 stationary frame (frame)
- 5 comb tooth electrodes
- 6, 46, 56 stoppers
- 6a chamfers
- 10 mirror face
- 56c convexities

[CLAIMS]

[Claim 1]

A moving structure comprising a moving plate, twin hinges constituting an axis of swing motion of the moving plate wherein an end of each hinge is connected to the moving plate, and a frame to which another end of each of the twin hinges is connected and which supports the hinges, and wherein

the moving plate is configured swingable with respect to the frame while twisting the twin hinges, characterized in that

stoppers are formed along the hinges at both sides of the hinges, so that a quantity of displacement of the moving plate in a direction parallel to an upper face of the moving plate is restrained by contacting a part of the moving structure when the moving plate displaces.

[Claim 2]

The moving structure in accordance with claim 1, characterized in that

recesses are provided on the moving plate so that they are formed to be concaved in a longitudinal direction of the hinges in the vicinities of portions pivoted by the hinges, and

the stoppers are integrally formed with the frame and formed to be located between the hinges and side end portions of the moving plate to which the recesses are formed.

[Claim 3]

The moving structure in accordance with claim 1,

characterized in that the moving plate has contacting protrusions formed to protrude toward the stationary frame respectively at positions distant from the hinges than the stoppers at both side portions of the hinges.

[Claim 4]

The moving structure in accordance with one of claim 1 to claim 3, characterized in that a chamfer of a round shape is formed at each corner of the stoppers.

[Claim 5]

The moving structure in accordance with one of claim 1 to claim 4, characterized in that the stoppers are configured to be the same electric potential as the hinges.

[Claim 6]

The moving structure in accordance with one of claim 1 to claim 5, characterized in that a sticking prevention film or a protrusion is formed on at least a part of each of the stopper so as not to occur sticking between the stopper and one which contacts the stopper.

[Claim 7]

A light scanning mirror having the moving structure in accordance with one of claim 1 to claim 6; and

a mirror face for reflecting incident light is provided on a top face of the moving plate.