

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 pivoted by hinges and driven to swing by comb tooth electrodes provided between a frame and the moving plate, 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, the comb tooth electrode used in such a light scanning mirror is configured of a lot of comb teeth which are formed too thin so as to generate large electrostatic force. When vibrations or an impact are/is applied to the light scanning mirror from outside and a quantity of displacement of the moving plate in a lateral direction becomes larger, the comb teeth provided on the moving plate may contact a stationary frame or the like, or the comb teeth provided on the stationary frame may contact the moving plate or the like. Since each comb tooth is thin and weak, it may be broken when contacting such a stationary frame or a moving plate.

[PARENT DOCUMENT 1] JP 2004-13099A

[DISCLOSURE OF INVENTION]

[PROBLEMS THAT THE INVENTION IS GOING TO SOLVE]

[0004]

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 comb tooth electrodes are nonbreakable even when an impact shock is

applied from outside.

[MEANS TO SOLVE THE PROBLEMS]

[0005]

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; a frame to which another end of each of the twin hinges is connected and which supports the hinges, and comb tooth electrodes, which are formed to interdigitate each other on a part of the moving plate and a part of the frame to face each other, and swing the moving plate with respect to the frame, characterized in that the stoppers, which are disposed to contact another portion of the moving structure except the comb tooth electrodes, when the moving plate displaces so as to restrain a quantity of displacement of the moving plate in a direction parallel to an upper face of the moving plate, are further comprised; and the stoppers are configured to be the same electric potential as that of another portion of the moving structure which contacts the stopper when the moving plate displaces in a lateral direction.

[0006]

The invention of claim 2 is characterized in that the stoppers are integrally formed with the moving plate or the frame, in the invention of claim 1.

[0007]

The invention of claim 3 is characterized in that a chamfer of a

round shape is formed at each corner of the stoppers, in the invention of claim 1 or claim 2.

[0008]

The invention of claim 4 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 3.

[0009]

The invention of claim 5 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 4.

[EFFECTS OF THE INVENTION]

[0011]

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, since the comb teeth of the comb tooth electrode may not contact the moving plate or the stationary frame or the like, breakage of the comb tooth electrode is prevented, and thus, crashworthy of the moving structure can be enhanced. Since the crashworthy can be enhanced by providing the stoppers in the vicinity of the comb tooth electrodes, the moving structure can be manufactured relatively easier.

[0012]

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.

[0013]

According to the invention of claim 3, 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.

[0014]

According to the invention of claim 4, 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.

[0015]

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 because occurrence of sticking is prevented by the sticking prevention

film or the protrusion.

[0016]

According to the invention of claim 6, 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]

[0017]

Hereinafter, a first embodiment of the present invention is described below with reference to figures. FIG. 1, 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).

[0018]

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. As shown in FIG. 1, 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. 2, 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.

[0019]

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 moving plate 2. As shown in FIG. 3, 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.

[0020]

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.

[0021]

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 on both sides of two comb tooth electrodes 5 respectively connected to the twin hinges 3 are electrically insulated from other portions of the stationary frame 4. The two supporting portions 4b are formed to locate at portions facing peripheral portions of the moving plate 2 except the portions where the electrodes 2a are formed, as described later.

[0022]

In this way, by forming the trenches 101, the stationary frame 4 is divided into the two supporting portions 4b which is to be at the same electric potential of the moving plate 2 connected to the twin hinges 3 and to which a voltage application area 10a is formed on a top face thereof and two portions which has the electrodes 4a and to which voltage application areas 10b are formed on top faces thereof. Since the trenches 101 divides 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 by three portions electrically insulated each other.

[0023]

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 the electrodes 4a respectively have many comb teeth. Each comb teeth of the electrodes 2a and the electrodes 4a is formed to be thinner for enabling to arrange them as much as possible in a limited space to provide the comb tooth electrodes 5. Gaps between the electrodes 2a and 4a are about 2 μ m to 5 μ m.

[0024]

The stoppers 6 are provided to restrain a quantity of displacement of the moving plate 2 in a lateral direction, that is, in a direction substantially perpendicular to an 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 moving plate 2 on the first silicon layer 200a. In this embodiment, the stoppers 6 are formed to protrude at four corners of the moving plate 2 positioned outside in arranging direction of the comb tooth electrodes 5 toward the stationary frame 4 facing the corresponding regions of the moving plate 2. The stoppers 6 are formed so that front ends of them near to the stationary frame 4 adjoin the supporting portions 4b of the stationary frame 4. The stoppers 6 are formed 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. The stoppers 6 are configured to protrude toward the regions of the supporting portions 4b of the stationary frame 4 arranged in parallel with the

hinges 3, and, the moving plate 2, the hinges 3 and the stoppers 6 become the same electric potential.

[0025]

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. The stoppers 6 are formed so that gaps between the stoppers 6 and the supporting portions 4b become narrower than gaps between the electrodes 2a and the stationary frame 4 and gaps between the electrodes 4a and the moving plate 2. In addition, sticking prevention films (not illustrated in the figures) are formed on regions 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 regions of the stoppers 6 facing the moving plate 2, for example.

[0026]

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.

[0027]

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.

[0028]

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 parallel with the stationary frame 4, that is, 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.

[0029]

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. FIG. 4 shows 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 to the light scanning mirror 1 from outside, it is in the state that gaps are formed between the stoppers 6 and the supporting portions 4b facing thereto. 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 a lateral direction (shown by arrow in the figure) from the normal state, that is, the direction substantially perpendicular to the axis of the swing motion and substantially in parallel with the top face of the SOI substrate 200 while deforming the hinge 3, as shown in the figure. When a quantity of the displacement of the moving plate 2 in the lateral direction becomes larger, the stopper 6 contacts a side end portion of the supporting portion 4b, so that the displacement of the moving plate 2 in the direction is restrained, and thus, the quantity of the displacement may not be increased no more. In a state that the

stopper 6 contacts the side end portion of the supporting portion 4b, the comb tooth of the electrodes 2a do not contact the stationary frame 4 and the comb tooth of the electrodes 4a do not contact the moving plate, so that the comb tooth electrodes 5 are protected.

[0030]

In addition, the light scanning mirror 1 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. The mirror face 10 is formed on a top face of the moving plate 2 and the voltage application areas 10a and 10b are formed on a top face of the stationary frame 4 by patterning the metal film.

[0031]

Subsequently, a shape which will be the stationary frame 4 is formed on the second silicon layer 220b by processing 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. A part of the oxidation film 220 other than the stationary frame 4 is 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. In addition, 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.

[0032]

As mentioned above, since the displacement of the moving plate 2 is restrained, and thus, the breakage of the comb tooth electrodes 5 can be prevented by providing the stoppers 6 in this embodiment, the crashworthy of the light scanning mirror 1 can be enhanced. 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 comb tooth electrodes 5 effectively. In addition, the chamfers 6a of round shape are formed on the stoppers 6 and there is no aculeate shape in the portion contacting to the stationary frame 4, so that it is hard to concentrate stress to the contacting portions of the stoppers 6 and the stationary frame 4, and it is possible to prevent the breakage of the stoppers 6 or the stationary frame 4.

[0033]

Furthermore, the stoppers 6 and the supporting portions 4b of the stationary frame 4 are at the same electric potential, and the sticking prevention films are formed on the regions of the stoppers 6 which may contact the supporting portions 4b. Therefore, even when the stopper 6 contacts the supporting portion 4b, sticking due to electrostatic force hardly occurs, and thus, it is possible to prevent that the moving plate 2 becomes immovable, surely. Still furthermore, since the stoppers 6 can be formed integrally with the moving plate 2, the light scanning mirror 6 can be manufactured relatively easily. In particular, since the stoppers 6 are formed simultaneously in the processes to form the moving plate 2 by processing the first silicon layer 200a, proper gaps between the

stoppers 6 and the stationary frame 4 can be assured and it is easily manufactured.

[0034]

In addition, in the first embodiment, it is possible to prevent the occurrence of sticking by forming convexities on the stoppers. FIG. 5 shows an example of the stopper having the convexities. Saw tooth shaped convexities 16a are formed at a portion of the stopper 16 which may contact the stationary frame 4 when the moving plate 2 displaces in the lateral direction. In this way, since the convexities 16a are formed on the stopper 16, when the stopper 16 contacts the stationary frame 4, contacting areas of them become smaller. Thereby, since affect of electrostatic force between the stopper 16 and the stationary frame 4 becomes smaller, occurrence of sticking can be prevented. In addition, the shapes of the convexities 16a are limited to the saw tooth shapes. The convexities 16a are preferably formed to have shapes not to concentrate stresses to contacting portions when the stopper 16 contacts the stationary frame 4. Furthermore, it is preferable to form sticking prevention films at portions of the stoppers 16 contacting the stationary frame 4 when the convexities 16a are formed on the stopper 16, so that occurrence of sticking can be prevented surely.

[0035]

Subsequently, a second embodiment of the present invention is described. FIG. 6 shows a light scanning mirror 21 in accordance with the sixth embodiment. Hereinafter, elements similar to those in

the above first embodiment are designated by the same reference marks, and only the portions different from the above mentioned first embodiment are described. The light scanning mirror 21 has a moving plate 22 of a circular shape and a stationary frame 24 formed to surround the moving plate 22, and two stoppers 26 respectively formed at substantially center areas of the free end portions of the moving plate 22. Although the stationary frame 24 is divided into three portions which are electrically insulated each other by forming trenches 101, the stationary frame 24 facing the stoppers 26 is not at the same electric potential as that of the stoppers 26, different from the first embodiment. Supporting portions 24b of the stationary frame 24 are disposed at regions to support the hinges 3 and not placed at regions to face the moving plate 22. In addition, regions of the stationary frame 24 facing the stoppers 26 may be at the same potential as that of the stoppers 26 by changing the arrangement of the trenches 101 and voltage application areas 10b. Other configurations of the light scanning mirror 21 are similar to that of the light scanning mirror 1 in the first embodiment. This light scanning mirror 21 can be manufactured easily by forming the shapes that the stoppers 26 are provided on the moving plate 22 on the first silicon layer 200a by processing the bulk micro machining technology.

[0036]

As shown in the figure, the comb tooth electrodes 5 are arranged along the end portions of the moving plate 22 at both sides

of the stoppers 26 formed at the substantially center portions of the free ends of the moving plate 22. In other words, the stoppers 26 are disposed in the vicinities of the sides of the comb tooth electrodes 5. Similar to the first embodiment, the stoppers 26 are formed so that gaps to the stationary frame 24 and them are a little narrower than gaps between the electrodes 2a of the comb tooth electrodes 5 and the stationary frame 24 or gaps between the electrodes 4a and the moving plate 22 in the normal state. In addition, sticking prevention films are formed at regions of the stopper 26 contacting the stationary frame 24 and chamfers 26a of round shape are formed at corners thereof.

[0037]

In the second embodiment, even when vibrations or a mechanical shock are/is applied from outside, one of the stoppers 26 contacts the stationary frame 24, and thus, the moving plate 22 displaces no more. Therefore, in this embodiment, it is possible to prevent the breakage of the comb tooth electrodes 5 and to enhance the crashworthy of the light scanning mirror 21 similar to the above first embodiment. Since the sticking prevention films are formed on the stoppers 26, sticking hardly occurs when the stopper 26 contacts the stationary frame 24. In addition, since the chamfers 26a are formed on the stoppers 26, it is possible to prevent the breakage of the stoppers 26 and the stationary frame 24.

[0038]

In addition, the present invention is not limited to the

configurations of the above embodiments, and it is possible to modify in various manner properly in a scope not to change the purpose of the invention. For example, the stoppers are not limited to be formed integrally with the moving plate, and they may be formed integrally with the stationary frame so as to protrude toward the moving plate from the stationary frame in the vicinity of the comb tooth electrodes. Even in this case, when the moving plate displaces in the lateral direction, the stopper contacts the moving plate so that the quantity of the displacement of the moving plate is restrained, and thus, the comb tooth electrodes can be protected.

[0039]

Furthermore, the light scanning mirror is not limited to one which can swing around a single axis as described in the above 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 provided is swingably pivoted on the moving frame, for example. In this case, by disposing stoppers in the vicinities of comb tooth electrodes between the moving frame and the stationary frame, a quantity of the displacement of the moving plate including the moving frame and the mirror can be restrained and the comb tooth electrodes can be protected. Similarly, by forming stoppers in the vicinities of comb tooth electrodes between the mirror and the moving frame, a quantity of displacement of the mirror serving as the moving plate with respect to the moving frame can be restrained and the comb tooth electrodes can be protected.

Furthermore, the light scanning mirror may be configured of a single silicon substrate or a metal plate instead of the SOI substrate. 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 this case, it is possible to restrain the displacement of the moving plate in the lateral direction, to prevent the breakage of the comb tooth electrodes and to enhance the crashworthy of the light scanning mirror by forming the stoppers in the vicinities of the comb tooth electrodes between the moving plate and the frames surrounding it.

[0040]

Still furthermore, the present invention is not limited to the light scanning mirror having the mirror face to scan light, and it is widely applicable to a moving structure that a moving plate which is configured to swingable with respect to the stationary frame by twin hinges is formed on a semiconductor substrate. In other words, it is possible to enhance the crashworthy of the moving structure by providing the stoppers in the vicinities of the comb tooth electrodes between the moving plate and the frame.

[BRIEF DESCRIPTION OF THE DRAWINGS]

[0041]

[FIG. 1] Perspective view showing a light scanning mirror which is a moving structure in accordance with a first embodiment of the present invention

- [FIG. 2] Plain view of the above light scanning mirror
- [FIG. 3] A-A sectional view in FIG. 2
- [FIG. 4] Plain view showing a portion of the above light scanning mirror in the vicinity of stoppers
- [FIG. 5] Plain view showing a modified example of the above light scanning mirror
- [FIG. 6] Perspective view showing a light scanning mirror in accordance with a second embodiment of the present invention

[LIST OF MARKS]

[0042]

- 1, 21 light scanning mirror (moving structure)
- 2, 22 moving plate
- 3 hinges
- 4, 24 stationary frame (frame)
- 5 comb tooth electrodes
- 6, 16, 26 stoppers
- 6a, 26a chamfers
- 10 mirror face
- 16c 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;

a frame to which another end of each of the twin hinges is connected and which supports the hinges, and

comb tooth electrodes, which are formed to interdigitate each other on a part of the moving plate and a part of the frame to face each other, and swing the moving plate with respect to the frame, characterized in that

the stoppers, which are disposed to contact another portion of the moving structure except the comb tooth electrodes, when the moving plate displaces so as to restrain a quantity of displacement of the moving plate in a direction parallel to an upper face of the moving plate, are further comprised; and

the stoppers are configured to be the same electric potential as that of another portion of the moving structure which contacts the stopper when the moving plate displaces in a lateral direction.

[Claim 2]

The moving structure in accordance with claim 1, characterized in that the stoppers are integrally formed with the moving plate or the frame.

[Claim 3]

The moving structure in accordance with claim 1 or claim 2, characterized in that a chamfer of a round shape is formed at each corner of the stoppers.

[Claim 4]

The moving structure in accordance with one of claim 1 to claim 3, 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 5]

A light scanning mirror having the moving structure in accordance with one of claim 1 to claim 4; and

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