Claims

1. MEMS ~~(100)~~ comprising:

a diaphragm ~~(102)~~;

a stroke structure ~~(104)~~ coupled to the diaphragm ~~(102)~~; and

at least two piezoelectric actuators ~~(106_1:106_n)~~ coupled to a plurality of mutually spaced-apart contact points ~~(110_1:110_m)~~ of the stroke structure ~~(104)~~ via a plurality of mutually spaced-apart connecting elements ~~(108_1:108_m)~~;

the at least two piezoelectric actuators ~~(106_1:106_n)~~ being configured to cause a stroke movement of the stroke structure ~~(104)~~ so as to deflect the diaphragm ~~(102)~~; and

wherein each of the at least two piezoelectric actuators is connected to at least two mutually spaced-apart contact points of the stroke structure via at least two mutually spaced-apart connecting elements.

2. MEMS ~~(100)~~ as claimed in the previous claim, wherein the plurality of mutually spaced-apart connecting elements ~~(108_1:108_m)~~ are connected to a plurality of mutually spaced-apart contact points ~~(112_1:112_m)~~ of the at least two piezoelectric actuators ~~(106_1:106_n)~~.

3. MEMS ~~(100)~~ as claimed in any of the previous claims, wherein ~~each of the at least two piezoelectric actuators (106_1:106_n) is connected to at least two mutually spaced-apart contact points (110_1:110_m) of the stroke structure (104) via at least two mutually spaced-apart connecting elements (108_1:108_m).~~

~~4. MEMS (100) as claimed in any of the previous claims, wherein the stroke structure (104) is coupled to the diaphragm (102) via a plurality of regions arranged with the diaphragm (102) along at least two at least partly mutually spaced-apart straight lines or curves.~~

~~5. MEMS (100) as claimed in any of the previous claims, wherein~~ the stroke structure ~~(104)~~ spans, perpendicularly to a direction ~~(114)~~ of the stroke movement, an area which corresponds to at least 30 % of an area of the diaphragm ~~(102)~~.

~~6~~4. MEMS ~~(100)~~ as claimed in any of the previous claims, wherein the stroke structure ~~(104)~~ is coupled to the diaphragm ~~(102)~~ via a plurality of regions ~~(104a;104b;104c)~~ arranged in a distributed manner.

~~7. MEMS (100) as claimed in any of the previous claims, wherein the stroke structure (104) comprises an I structure, an L structure, an H structure, an X structure, an O structure, or a cross-shaped structure within a sectional plane which runs perpendicularly to a direction (114) of the stroke movement.~~

~~8. MEMS (100) as claimed in any of the previous claims, wherein a lever arm disposed between one of the points of application of force of the stroke structure (104) to the diaphragm (102) and a nearest location point of a diaphragm suspension (118) is half the size, at the most, of a lever arm of the at least two piezoelectric actuators (106_1:106_n).~~

~~9~~5. MEMS ~~(100)~~ as claimed in any of the previous claims, wherein a cross-sectional area of the stroke structure ~~(104)~~ that is perpendicular to a direction ~~(114)~~ of the stroke movement of the stroke structure ~~(104)~~ is smaller than a sum of piezoelectrically active actuator areas of the at least two piezoelectric actuators ~~(106_1:106_n)~~.

~~10. MEMS (100) as claimed in any of the previous claims, wherein the stroke structure (104) comprises a plurality of mutually connected beams (104a;104b;104c), each of which is coupled to the diaphragm (102) at least partially at a front end.~~

~~11. MEMS (100) as claimed in any of the previous claims, wherein the at least two piezoelectric actuators (106_1:106_n) are configured as bending beams.~~

~~12. MEMS (100) as claimed in any of the previous claims, wherein the stroke structure (104) is symmetrical, and wherein the at least two piezoelectric actuators (106_1:106_n) are arranged symmetrically with respect to a center of gravity (120) of the stroke structure (104).~~

13. MEMS (100) as claimed in the previous claim, wherein the plurality of mutually spaced-apart contact points (110_1:110_m) of the stroke structure (104) are arranged symmetrically with respect to the center of gravity (120) of the stroke structure (104).

14. MEMS (100) as claimed in any of the previous claims, wherein the at least two piezoelectric actuators (106_1:106_n) are arranged within a plane in an idle position, and wherein the at least two piezoelectric actuators (106_1:106_n) are configured to cause a stroke movement of the stroke structure (104) such that a direction (114) of the stroke movement extends perpendicularly to the plane of the piezoelectric actuators (106_1:106_n).

15. MEMS (100) as claimed in any of the previous claims, wherein the plurality of mutually spaced-apart connecting elements (108_1:108_m) comprise spring elements.

16. MEMS (100) as claimed in the previous claim, wherein each of the spring elements (108_1:108_m) includes at least one flexion spring element (108B), at least one torsion spring element (108T), or a combination of at least one flexion spring element (108B) and at least one torsion spring element (108T).

17. MEMS (100) as claimed in any of the previous claims, wherein the diaphragm (102) extends in parallel with a first surface (122) and a second surface (124) of the MEMS (100), the diaphragm (102) being configured to separate, when the MEMS (100) is used as intended, the first surface (122) and the second surface (124) of the MEMS (100) from each other in a fluidic or gas-shaped manner.

18. MEMS (100) as claimed in any of the previous claims, wherein the diaphragm (102) comprises a rigid region (150) and a flexible region (152), the stroke structure (104) being coupled to the rigid region (150) of the diaphragm (102).

19. MEMS (100) as claimed in the previous claim, wherein the rigid region (150) of the diaphragm (102) is formed by an extended stroke structure (104).

20. MEMS (100) as claimed in any of the previous claims, the MEMS (100) comprising at least one piezoelectric position sensor (140) configured to provide a sensor signal dependent on the deflection of the diaphragm (102).

21. MEMS (100) as claimed in the previous claim, the MEMS (100) comprising at least four piezoelectric actuators (106_1:106_n), two of the at least four piezoelectric actuators (106_1:106_n) being configured as piezoelectric position sensors, said at least four piezoelectric actuators (106_1:106_n) being arranged symmetrically with respect to a center of gravity in such a manner that the two piezoelectric actuators (106_1:106_n) configured as piezoelectric position sensors and the remaining piezoelectric actuators (106_1:106_n) each are arranged symmetrically with respect to the center of gravity of the stroke structure (104).

22. MEMS (100) as claimed in claim 20, the MEMS (100) comprising at least one stack of two mutually insulated piezoelectric layers, one of the two layers (140) forming the at least one piezoelectric sensor, and the other one of the two layers (142) forming one of the at least two piezoelectric actuators (106_1:106_n).

23. MEMS (100) as claimed in claim 22, wherein the two mutually insulated piezoelectric layers comprise different materials.

24. MEMS (100) as claimed in claim 20, wherein the piezoelectric position sensor (140) and one piezoelectric actuator of the at least two piezoelectric actuators (106_1:106_n) are formed by a common piezoelectric layer.

25. MEMS (100) as claimed in any of the previous claims, the MEMS (100) comprising at least one piezoresistive or one capacitive position sensor that is configured to provide a sensor signal dependent on the deflection of the diaphragm (102).

26. MEMS (100) as claimed in any of the previous claims, wherein the stroke structure (104) comprises silicon.

27. MEMS (100) as claimed in any of the previous claims, wherein the stroke structure (104) comprises at least three portions (104a;104b;104c) arranged to form an H-shaped stroke structure (104), so that the stroke structure (104) is H-shaped within

the sectional plane that runs perpendicularly to the direction (114) of the stroke movement of the stroke structure (104).

28. MEMS (100) as claimed in claim 27, wherein a first piezoelectric actuator (106_1) of the at least two piezoelectric actuators (106_1:106_n) is arranged, outside the H-shaped stroke structure (104), along a first portion (104a) of the three portions (104a;104b;104c) of the stroke structure (104), and wherein a second piezoelectric actuator (106_2) of the at least two piezoelectric actuators (106_1:106_n) is arranged, outside the H-shaped stroke structure (104), along a second portion (104b) of the three portions (104a;104b;104c) of the stroke structure (104), the first portion (104a) and the second portion (104b) of the stroke structure (104) extending in parallel with each other.

29. MEMS (100) as claimed in claim 28, wherein a third piezoelectric actuator (106_3) of the at least two piezoelectric actuators (106_1:106_n) is at least partly arranged, inside the H-shaped stroke structure (104), along a first side of a third portion (104c) of the three portions (104a;104b;104c) of the stroke structure (104), a fourth piezoelectric actuator (106_4) of the at least two piezoelectric actuators (106_1:106_n) being at least partly arranged, inside the H-shaped stroke structure (104), along a second side, located opposite the first side, of the third portion (104c) of the stroke structure (104), the third portion (104c) extending perpendicularly to the first portion (104a) and the second portion (104b).

30. MEMS (100) as claimed in any of claims 28 or 29, wherein the first piezoelectric actuator (106_1) extends at least over the entire first portion (104a) of the stroke structure (104) and is connected to at least two of the mutually spaced-apart contact points (110_1:110_m) of the first portion (104a) of the stroke structure (104) via at least two of the mutually spaced-apart connecting elements (108_1:108_m), the second piezoelectric actuator (106_2) extending at least over the entire second portion (104b) of the stroke structure (104) and being connected to at least two of the mutually spaced-apart contact points (110_1:110_m) of the second portion (104b) of the stroke structure (104) via at least two of the mutually spaced-apart connecting elements (108_1:108_m).

31. MEMS (100) as claimed in any of claims 28 or 29, wherein the first piezoelectric actuator (106_1) and a fifth piezoelectric actuator (106_5) of the at least two pie-

zoelectric actuators (106_1:106_n) are arranged, outside the stroke structure (104), along the first portion (104a) of the stroke structure (104), the second piezoelectric actuator (106_2) and a sixth piezoelectric actuator (106_6) of the at least two piezoelectric actuators (106_1:106_n) being arranged, outside the stroke structure (104), along the second portion (104b) of the stroke structure (104);

wherein the first piezoelectric actuator (106_1) and the fifth piezoelectric actuator (106_5) are each connected to at least one of the mutually spaced-apart contact points (110_1:110_m) of the first portion (104a) of the stroke structure (104) via at least one of the mutually spaced-apart connecting elements (108_1:108_m), the second piezoelectric actuator (106_2) and the sixth piezoelectric actuator (106_6) each being connected to at least one of the mutually spaced-apart contact points (110_1:110_m) of the second portion (104b) of the stroke structure (104) via at least one of the mutually spaced-apart connecting elements (108_1:108_m).

32. MEMS (100) as claimed in claim 31, wherein the first portion (104a) is subdivided into a first segment (104a_1) and a second segment (104a_2), the first piezoelectric actuator (106_1) being arranged along the first segment (104a_1) of the first portion (104a) and being connected to the first segment (104a_1) of the first portion (104a) via the respective connecting element, the fifth piezoelectric actuator (106_5) being arranged along the second segment (104a_2) of the first portion (104a) and being connected to the second segment (104a_2) of the first portion (104a) via the respective connecting element; and

wherein the second portion (104b) is subdivided into a first segment (104b_1) and a second segment (104b_2), the second piezoelectric actuator (106_2) being arranged along the first segment (104b_1) of the second portion (104b) and being connected to the first segment (104b_1) of the second portion (104b) via the respective connecting element, the sixth piezoelectric actuator (106_6) being arranged along the second segment (104b_2) of the second portion (104b) and being connected to the second segment (104b_2) of the second portion (104b) via the respective connecting element.

33. MEMS (100) as claimed in any of claims 31 or 32, wherein the third piezoelectric actuator (106_3) and a seventh piezoelectric actuator (106_7) of the at least two piezoelectric actuators (106_1:106_n) are at least partly arranged, inside the

stroke structure (104), along the first side of the third portion (104c) of the stroke structure (104), the fourth piezoelectric actuator (106_4) and an eighth piezoelectric actuator (106_8) of the at least two piezoelectric actuators (106_1:106_n) being at least partly arranged, inside the stroke structure (104), along the second side of the third portion (104c) of the stroke structure (104).

34. MEMS (100) as claimed in claim 33, wherein the third portion (104c) is subdivided into a first segment (104c_1) and a second segment (104c_2), the third piezoelectric actuator (106_3) being arranged along a first side of the first segment (104c_1) of the third portion (104c), the fourth piezoelectric actuator (106_4) being arranged along a second side, located opposite the first side, of the first segment (104c_1) of the third portion (104c), the seventh piezoelectric actuator (106_7) being arranged along a first side of the second segment (104c_2) of the third portion (104c), the eighth piezoelectric actuator (106_8) being arranged along a second side, located opposite the first side, of the second segment (104c_2) of the third portion (104c).

35. MEMS (100) as claimed in any of the previous claims, wherein the stroke structure (104) comprises a plurality of stroke bodies.

36. MEMS (100) as claimed in claim 35, wherein at least two stroke bodies of the plurality of stroke bodies are connected to each other via an extended stroke body.

37. MEMS (100) as claimed in any of the previous claims, wherein the plurality of mutually spaced-apart connecting elements (108_1:108_m) do not extend across the center of the depression.

38. System (200) comprising:

a MEMS (100) as claimed in any of claims 1 to 37; and

a control means (202) configured to control the at least two piezoelectric actuators (106_1:106_n) of the MEMS (100);

the MEMS (100) comprising at least one piezoelectric position sensor (140) configured to provide a sensor signal (141) dependent on the deflection of the diaphragm (102); and

the control means (202) being configured to control the at least two piezoelectric actuators (106_1:106_n) of the MEMS (100) in a regulated manner on the basis of the sensor signal (141).

398. Utilization of the MEMS (100) as claimed in any of claims 1 to 36 6 for sound generation, for ultrasound generation, for displacing liquids, for displacing gasses, or for generating droplets of liquid.

409. MEMS loudspeaker (100) for generating sound waves within the audible wavelength spectrum, comprising

a diaphragm (102),

a stroke structure (104) coupled to the diaphragm (102), and

at least two piezoelectric actuators (106_1:106_n),

by means of which a stroke movement of the stroke structure (104) can be caused for deflecting the diaphragm (102),

characterized in that

the piezoelectric actuators (106_1:106_n) are connected to a plurality of mutually spaced-apart contact points (110_1:110_m) of the stroke structure (104) via a plurality of mutually spaced-apart flexible connecting elements (108_1:108_m), and that each of the at least two piezoelectric actuators is connected to at least two mutually spaced-apart contact points of the stroke structure via at least two mutually spaced-apart connecting elements.

4110. MEMS loudspeaker as claimed in claim 109, characterized in that the diaphragm (102) is connected to the stroke structure (104) at a front end of the stroke structure (104) in a direct manner, and/or the piezoelectric actuators (106_1:106_n) are

connected to the stroke structure ~~(104)~~ on at least one side face of the stroke structure ~~(104)~~, in particular on two opposite side faces, in an indirect manner via the connecting elements ~~(108_1:108_m)~~.

~~42~~11. MEMS loudspeaker as claimed in any of the previous claims ~~40~~ 9 or ~~41~~10, characterized in that the plurality of connecting elements ~~(108_1:108_m)~~ that are mutually spaced-apart in particular in the transverse direction of the MEMS loudspeaker are connected to a plurality of mutually spaced-apart contact points ~~(112_1:112_m)~~ of the at least two piezoelectric actuators ~~(106_1:106_n)~~.

~~43~~12. MEMS loudspeaker as claimed in any of the previous claims ~~40~~ 9 to ~~42~~11, characterized in that ~~each of the at least two piezoelectric actuators (106_1:106_n) is connected to at least two mutually spaced-apart contact points (110_1:110_m) of the stroke structure (104) via at least two mutually spaced-apart connecting elements (108_1:108_m).~~

~~44. MEMS loudspeaker as claimed in any of the previous claims 40 to 43, characterized in that~~ the stroke structure ~~(104)~~ is coupled to the diaphragm ~~(102)~~ via a plurality of regions arranged ~~with the diaphragm (102)~~ along at least two at least partly mutually spaced-apart straight lines or curves.

~~45. MEMS loudspeaker as claimed in any of the previous claims 40 to 44, characterized in that the stroke structure (104) is coupled to the diaphragm (102) via a plurality of regions (104a;104b;104c) arranged in a distributed manner.~~

~~46. MEMS loudspeaker as claimed in any of the previous claims 40 to 45, characterized in that the stroke structure (104) comprises a plurality of mutually connected beams (104a;104b;104c), each of which is coupled to the diaphragm (102) at least partially at a front end.~~

~~47. MEMS loudspeaker as claimed in any of the previous claims 40 to 46, characterized in that the at least two piezoelectric actuators (106_1:106_n) are configured as bending beams.~~

~~48. MEMS loudspeaker as claimed in any of the previous claims 40 to 47, characterized in that the at least two piezoelectric actuators (106_1:106_n) are arranged~~

within a first plane in an idle position, that the diaphragm (102) is arranged within a second plane spaced apart from the former in the stroke direction, and/or

in that the stroke structure (104) extends in the stroke direction, starting from the diaphragm, (102) in the direction of the second plane, in particular as far as or beyond the latter.

49. MEMS loudspeaker as claimed in any of the previous claims 40 to 48, characterized in that at least one of the connecting elements (108_1:108_m) comprises a spring element, and/or in that the spring element (108_1:108_m), in particular each one, includes at least one flexion spring element (108B) and/or at least one torsion spring element (108T).

50. MEMS loudspeaker as claimed in any of the previous claims 40 to 49, characterized in that the piezoelectric actuators (106_1:106_n) comprise, in a cross-sectional view of the MEMS loudspeaker, a fixedly clamped first end and a movable second end, respectively, along their longitudinal axes, and/or

in that the flexion spring element (108B) extends in the longitudinal direction, and/or the torsion spring element (108T) extends in the transverse direction, of the piezoelectric actuator (106_1:106_n).

51. MEMS loudspeaker as claimed in any of the previous claims 40 to 50, characterized in that the flexion spring element (108B) and the torsion spring element (108T) of a connecting element (108_1:108_m) are rotated by 90° in relation to each other in a top view of the MEMS loudspeaker.

52. MEMS loudspeaker as claimed in any of the previous claims 40 to 51, characterized in that the diaphragm (102) comprises a rigid region (150) and a flexible region (152), the stroke structure (104) being coupled to the rigid region (150) of the diaphragm (102), the rigid region (150) of the diaphragm (102) preferably being formed by an extended stroke structure (104).

53. MEMS loudspeaker as claimed in any of the previous claims 40 to 52, characterized in that the MEMS loudspeaker (100) comprises least four piezoelectric actua-

~~tors (106_1:106_n) arranged symmetrically with respect to the center of gravity of the stroke structure (104).~~

~~54. MEMS loudspeaker as claimed in any of the previous claims 40 to 53, characterized in that the stroke structure (104) comprises several stroke bodies and/or in that at least two stroke bodies are connected to each other via an extended stroke body.~~

~~55~~13. MEMS loudspeaker ~~(100)~~ for generating sound waves within the audible wavelength spectrum, comprising

a diaphragm ~~(102)~~,

a stroke structure ~~(104)~~ coupled to the diaphragm ~~(102)~~, and

at least one piezoelectric actuator ~~(106_1:106_n)~~ by means of which a stroke movement of the stroke structure ~~(104)~~ can be caused for deflecting the diaphragm ~~(102)~~,

characterized in that

the MEMS loudspeaker ~~(100)~~ comprises at least one position sensor ~~(140)~~ configured to provide a sensor signal dependent on the deflection of the diaphragm ~~(102)~~, and that each of the at least two piezoelectric actuators is connected to at least two mutually spaced-apart contact points of the stroke structure via at least two mutually spaced-apart connecting elements.

~~56~~14. MEMS loudspeaker ~~(100)~~ as claimed in previous claim ~~55~~13, characterized in that the actuator ~~(106_1:106_n)~~ is operable in a regulated manner as a function of the sensor signal by means of a control means ~~(202)~~ provided for this purpose;

~~57. MEMS loudspeaker as claimed in any of the previous claims 55 to 56, characterized in that the MEMS loudspeaker (100) comprises at least one piezoelectric and/or capacitive position sensor (140).~~

~~58. MEMS loudspeaker as claimed in any of the previous claims 55 to 57, characterized in~~

or that the position sensor ~~(140)~~ is integrated in the actuator ~~(106_1:106_n);~~.

~~59. MEMS loudspeaker as claimed in any of the previous claims 55 to 58, characterized in~~

or that the sensor electrodes of the integrated position sensor ~~(140)~~ are configured as two-dimensional or interdigital electrodes and/or are electrically insulated from the actuator electrodes;~~.~~

~~60. MEMS loudspeaker as claimed in any of the previous claims 55 to 59, characterized in~~

or that the piezoelectric position sensor ~~(140)~~ and the piezoelectric actuator ~~(106_1:106_n)~~ are configured by a common piezoelectric layer.

~~61. MEMS loudspeaker as claimed in any of the previous claims 55 to 60, characterized in that the common piezoelectric layer comprises a sensor area forming the position sensor (140) and an actuator area forming the actuator (106_1:106_n), which is electrically insulated from the sensor area, in particular, the sensor area preferably taking up a smaller surface area as compared to the actuator area.~~

~~62. MEMS loudspeaker as claimed in any of the previous claims 55 to 61, characterized in that the piezoelectric position sensor (140) and the piezoelectric actuator (106_1:106_n) are configured by a separate piezoelectric layer, respectively, the actuator (106_1:106_n) preferably comprising a stack of at least two mutually insulated piezoelectric layers, at least part of the one layer of which forms the at least one piezoelectric position sensor (140), and at least part of the other layer (142) forms the at least one piezoelectric actuator (106_1:106_n).~~

~~63. MEMS loudspeaker as claimed in any of the previous claims 55 to 62, characterized in that the stack is oriented in the direction of the stroke axis so that the piezoelectric layers are arranged one above the other, or in that the stack is oriented~~

~~transversely to the stroke axis so that the piezoelectric layers are arranged adjacently to one another.~~

~~64. MEMS loudspeaker as claimed in any of the previous claims 55 to 63, characterized in that the position sensor (140) and the at least one actuator (106_1:106_n) are separate from each other.~~

~~65. MEMS loudspeaker as claimed in any of the previous claims 55 to 64, characterized in that the MEMS loudspeaker (100) comprises several actuators (106_1:106_n), at least one of which can be used as a position sensor (140).~~

~~66. MEMS loudspeaker as claimed in any of the previous claims 55 to 65, characterized in that several actuators (106_1:106_n) and/or position sensors (140) are arranged opposite one another in pairs, the MEMS loudspeaker (100) preferably comprising at least four piezoelectric actuators (106_1:106_n) arranged symmetrically with respect to the center of gravity of the stroke structure (104), and/or in that two of the at least four piezoelectric actuators (106_1:106_n) are configured as piezoelectric position sensors (140).~~

~~67. MEMS loudspeaker as claimed in any of the previous claims 55 to 66, characterized in that the at least one actuator (106_1:106_n) and/or position sensor (140) is connected to the stroke structure (104) via at least one, in particular flexible, connecting element (108_1:108_m).~~

~~68. MEMS loudspeaker as claimed in any of the previous claims 55 to 67, characterized in that the diaphragm (102) is connected to the stroke structure (104) at a front end of the stroke structure (104) in a direct manner, and/or the piezoelectric actuators (106_1:106_n) and/or position sensors (140) are connected to the stroke structure (104) on at least one side face of the stroke structure (104), in particular on two opposite side faces, in an indirect manner via the connecting elements (108_1:108_m).~~

~~69~~15. Regulating unit ~~(200)~~ for operating a MEMS loudspeaker in a regulated manner, comprising a MEMS loudspeaker ~~(100)~~ as claimed in any of the previous claims ~~55~~ 10 to ~~68~~14, and

a control means (202) configured to control a piezoelectric actuator (106_1:106_n) of the MEMS loudspeaker (100),

characterized in that

the MEMS loudspeaker (100) comprises at least one piezoelectric position sensor (140) configured to provide the control means (202) with a sensor signal (141) dependent on the deflection of a diaphragm (102) of the MEMS loudspeaker (100), and

in that the control means (202) is configured to control the at least one piezoelectric actuator (106_1:106_n) of the MEMS loudspeaker (100) in a regulated manner on the basis of the sensor signal (141).