

SOUND TRANSDUCER ARRANGEMENT

The present invention relates to a MEMS sound transducer, in particular for
5 generating and/or detecting sound waves in the audible wavelength
spectrum, comprising a carrier; a diaphragm, which is connected to the
carrier and is deflectable with respect thereto along a reciprocation axis; at
least one piezoelectric element for generating and/or detecting a deflection of
the diaphragm, which is spaced apart from the diaphragm in the direction of
10 the reciprocation axis and comprises a first end connected to the carrier and
a second end deflectable in the direction of the reciprocation axis; and a
coupling element, which extends in the direction of the reciprocation axis
between the piezoelectric element and the diaphragm and connects the
second end of the piezoelectric element to the diaphragm.

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WO 2016/034665 A1 describes a MEMS, which comprises a diaphragm, a
reciprocating structure, which is coupled to the diaphragm, and at least two
piezoelectric actuators, which are connected, via a plurality of connecting
elements spaced apart from each other, to a plurality of contact points of the
20 reciprocating structure spaced apart from each other, wherein the at least
two piezoelectric actuators are designed for inducing a reciprocating motion
of the reciprocating structure in order to deflect the diaphragm. A
disadvantage of this MEMS, however, is that a performance is limited.

25 The object of the present invention is to improve the related art.

The object is achieved by means of a MEMS sound transducer having the
features of independent claim 1.

30 The invention relates to a MEMS sound transducer, which can be operated,
for example, in order to generate and/or detect sound waves in the audible
wavelength spectrum. The MEMS sound transducer can be arranged, for

example, in a smartphone, in headphones, or in another electrical device. The MEMS sound transducer can also be operated, however, for generating and/or detecting ultrasonic waves. The MEMS sound transducer can then be arranged, for example, in medical and/or technical diagnostic devices, in
5 distance sensors, or the like.

Furthermore, the MEMS sound transducer comprises a carrier and a diaphragm, which is connected to the carrier and is deflectable with respect thereto along a reciprocation axis. The diaphragm can be connected in its
10 entire edge area to the carrier. With the aid of the diaphragm, on the one hand, sound waves can be generated. For this purpose, the diaphragm can be caused to vibrate, which also causes the air situated above the diaphragm to vibrate. The propagating vibrations are the sound waves, which transport a tone. On the other hand, the diaphragm can also be caused to vibrate,
15 however. If sound waves impact the diaphragm, the diaphragm also begins to vibrate.

Moreover, the MEMS sound transducer comprises at least one piezoelectric element, which is spaced apart from the diaphragm in the direction of the
20 reciprocation axis, for generating and/or detecting a deflection of the diaphragm. The piezoelectric element can be deflected with the aid of a voltage. If the piezoelectric element itself is deflected by a force acting upon the piezoelectric element, it generates a voltage. The piezoelectric element comprises a first end, which is connected to the carrier. In addition, the
25 piezoelectric element comprises a second end, which is deflectable in the direction of the reciprocation axis.

In order to connect the second end of the piezoelectric element to the diaphragm, the MEMS sound transducer comprises a coupling element,
30 which extends in the direction of the reciprocation axis between the piezoelectric element and the diaphragm. The deflection of the piezoelectric element generated by the voltage can be transmitted to the diaphragm with

the aid of the coupling element in order to generate sound waves. With the aid of an electrical signal, the diaphragm can be set into corresponding vibrations via the coupling element, so that, for example, a tone can be generated. The vibrations of the sound waves can also be transmitted, with
 5 the aid of the coupling element, from the diaphragm to the piezoelectric element, which converts them into the electrical signal.

Furthermore, the at least one piezoelectric element and the coupling element, together, form a cantilever arm, which is clamped on one side and
 10 comprises a clamped end, formed by the first end of the piezoelectric element, and a free end formed by the coupling element. As a result, the cantilever arm can oscillate freely at the free end. Consequently, the piezoelectric element can undergo a high deflection along the reciprocation axis. For example, sound waves having a high amplitude can therefore be
 15 generated.

Furthermore, the MEMS loudspeaker has a high linearity. When the piezoelectric element is acted upon by the electrical signal, the free end deflects. Due to the fact that the piezoelectric element and the coupling
 20 element are designed as a cantilever arm, the deflection of the free end is linearly proportional to the instantaneous amplitude of the electrical signal. The sound waves generated as a result also have a sound amplitude, which is linearly proportional to the deflection of the free end. The sound waves generated from the electrical signal with the aid of the MEMS sound
 25 transducer according to the invention therefore have a high linearity.

Due to the design of the piezoelectric element and the coupling element as a cantilever arm, the diaphragm can also be acted upon by the piezoelectric element with the aid of great force. As a result, the diaphragm can be
 30 advantageously deflected or caused to vibrate.

Moreover, the MEMS sound transducer comprises multiple cantilever arms. As a result, the diaphragm can be deflected with the aid of a greater force.

According to the invention, at least two cantilever arms are arranged one
5 behind the other, in a top view. As a result, the at least two cantilever arms
can be arranged in a straight line, one behind the other. The at least two
cantilever arms can be arranged with respect to one another in such a way
that they extend on a common line. As a result, the MEMS sound transducer
can be designed to be space-saving, since a width of the MEMS sound
10 transducer can be kept small due to the arrangement of the cantilever arms
one behind the other. In addition, as a result, the diaphragm can be deflected
linearly, i.e., linearly with respect to the deflection of the two cantilever arms.

In one advantageous enhanced embodiment of the invention, the cantilever
15 arm is connected, in the area of its free end, exclusively to the diaphragm. As
a result, the free end can oscillate freely, without being affected by anything
else with respect to the oscillation. The free end is not impeded or
decelerated with respect to the oscillation, for example, by a further
component. As a result, for example, the high linearity of the MEMS sound
20 transducer is possible. In addition, as a result, a high deflection of the
diaphragm can be achieved with the aid of a great force.

Furthermore, it is advantageous when an open area is formed, in a side view,
between the side of the coupling element facing away from the actuator, and
25 the carrier. As a result, the coupling element is spaced apart from the carrier
and can oscillate freely.

It is also advantageous when the open area has a U-shape, in a top view, so
that the cantilever arm is spaced apart from the carrier at its free end and at
30 both of its longitudinal sides. As a result, only the clamped end of the
cantilever arm has contact with the carrier, so that the longitudinal sides and
the free end can oscillate freely with respect to the carrier.

It is advantageous when the carrier comprises at least one recess, in which the cantilever arm is arranged. The recess can be completely bordered by the carrier. Furthermore, the recess can extend completely through the carrier in the direction of the reciprocation axis, so that the recess has an upper opening and a lower opening. One of the two openings can be covered by the diaphragm.

When only one single cantilever arm is arranged in the recess, this is also advantageous. In this case, the cantilever arm can not be impeded by another cantilever arm with respect to the deflection along the reciprocation axis.

Additionally, it is advantageous when the MEMS sound transducer comprises multiple cantilever arms, which are arranged laterally adjacent to one another, in the top view. As a result, the force onto the diaphragm can be increased. In addition, with the aid of multiple cantilever arms spaced apart from one another, the diaphragm can be deflected uniformly and, in particular, in a planar manner. Consequently, the sound waves can be generated and/or detected in a planar manner. As a result, the cantilever arms can be arranged, for example, in a square, a rectangle, or another planar geometric figure or polygon. One cantilever arm can be arranged in one corner of the aforementioned figure or polygon in each case.

It is also advantageous when at least two cantilever arms are identically oriented with respect to one another. Additionally or alternatively, at least two cantilever arms can be oriented opposite to each other. As a result, the diaphragm can be advantageously deflected.

Moreover, it is advantageous when at least two adjacently arranged and identically oriented cantilever arms are connected to each other in the area of the free end with the aid of the coupling element. When the two cantilever

arms are adjacently arranged, their longitudinal sides face one another. Due to the connection of the two cantilever arms with the aid of the coupling element, the force of the two cantilever arms can be combined in the deflection.

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It is advantageous when the coupling element is connected to the piezoelectric element with the aid of an articulated joint, so that the coupling element is rotatable in relation to the piezoelectric element. The articulated joint can be, for example, an elastic articulated joint or a flexible articulated joint. With the aid of the rotatability of the coupling element, the coupling element can remain aligned in parallel to the diaphragm during the deflection of the piezoelectric element. As a result, the diaphragm can be loaded to a lesser extent in a contact area between the coupling element and the diaphragm.

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It is also advantageous when the piezoelectric element and the coupling element are formed as one piece of the same material. As a result, the piezoelectric element can be manufactured with the coupling element arranged thereon, for example, in one manufacturing step.

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Moreover, it is advantageous when the MEMS sound transducer is a MEMS loudspeaker. Additionally or alternatively, the MEMS sound transducer can also be a MEMS microphone.

Further advantages of the invention are described in the following exemplary embodiments. Wherein:

figure 1 shows a perspective view of a MEMS sound transducer comprising a carrier, a piezoelectric element, and a coupling element,

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- figure 2** shows a lateral sectional view of a MEMS sound transducer comprising a cantilever arm,
- figure 3** shows a lateral sectional view of a MEMS sound transducer comprising two oppositely oriented cantilever arms,
- figure 4** shows a lateral sectional view of a MEMS sound transducer comprising two identically oriented cantilever arms,
- figure 5** shows a top view of a MEMS sound transducer comprising two cantilever arms,
- figure 6** shows a top view of a MEMS sound transducer comprising one cantilever arm,
- figure 7** shows a lateral sectional view of a MEMS sound transducer comprising two cantilever arms and one coupling plate, and
- figure 8** shows a lateral sectional view of a MEMS sound transducer comprising a spacer element between the diaphragm and the coupling elements.

Figure 1 shows a perspective view of a MEMS sound transducer 1. In order to explain the mode of operation, initially only one cantilever arm 9 is shown. With the aid of the MEMS sound transducer 1, for example, sound waves in the audible wavelength spectrum can be generated, so that this can be operated as a MEMS loudspeaker. Additionally or alternatively, with the aid of the MEMS sound transducer 1, sound waves in the audible wavelength spectrum can also be detected, so that this can be operated as a MEMS microphone. Furthermore, the MEMS sound transducer 1 can be arranged, for example, in a smartphone, in order to make it possible to make a

telephone call or listen to music. The MEMS sound transducer 1 can also be arranged, for example, in headphones.

One further area of application of the MEMS sound transducer 1 can also be
 5 the generation and/or detection of ultrasonic waves, however. The MEMS sound transducer 1 can be arranged, for example, in an ultrasonic sensor, for example, a distance sensor.

Furthermore, the MEMS sound transducer 1 comprises a carrier 2, which can
 10 form a framework of the MEMS sound transducer 1. The carrier 2 can comprise, for example, a semiconductor substrate, which can be manufactured in an etching process. A diaphragm 3 (not shown here), which is connected to the carrier 2, for example, fully circumferentially, can be arranged on the carrier 2. The diaphragm 3 is deflectable along a
 15 reciprocation axis 4. With the aid of the deflection of the diaphragm 3, the air situated above the diaphragm 3 can be caused to vibrate, so that the sound waves are generated. However, the diaphragm 3 itself can also be caused to vibrate and, therefore, can be deflected, by the vibrating air. The diaphragm 3 can therefore detect the sound waves.

20 In order to detect and/or generate the deflection of the diaphragm 3, the MEMS sound transducer 1 comprises at least one piezoelectric element 5 spaced apart from the diaphragm 3 in the direction of the reciprocation axis 4. The piezoelectric element 5 can be deflected with the aid of an electrical
 25 signal, which encompasses, for example, music, wherein the deflection is transmitted onto the diaphragm 3, so that the sound waves are generated. The piezoelectric element 5 therefore acts as a piezoelectric actuator. The MEMS sound transducer 1 is operated as a MEMS loudspeaker in this case. If the piezoelectric element 5 is deflected by the diaphragm 3, however, the
 30 piezoelectric element 5 generates an electrical signal, which corresponds to the sound waves picked up by the diaphragm 3. The piezoelectric element 5

therefore acts as a piezoelectric sensor. The MEMS sound transducer 1 is then operated as a MEMS microphone.

5 The piezoelectric element 5 also comprises a first end 6, which is connected to the carrier 2. Furthermore, the piezoelectric element 5 comprises a second end 7, which is deflectable in the direction of the reciprocation axis 4.

10 The MEMS sound transducer 1 also comprises a coupling element 8, which extends in the direction of the reciprocation axis 4 between the piezoelectric element 5 and the diaphragm 3 and connects the second end 7 of the piezoelectric element 5 to the diaphragm 3. The coupling element 8 therefore transmits the deflection of the piezoelectric element 5 onto the diaphragm 3 when the MEMS sound transducer 1 is operated as a loudspeaker. In addition, the coupling element 8 transmits the deflection of the diaphragm 3
15 onto the piezoelectric element 5 when the MEMS sound transducer 1 is operated as a microphone.

Preferably, the carrier 2 and the coupling element 8 can be formed from an identical material, such as a semiconductor material. Furthermore, the carrier
20 2 and the coupling element 8 can have an identical thickness in the direction of the reciprocation axis 4. For example, the carrier 2 and the coupling element 8 can be formed together in a layering method, wherein the hollow spaces around the carrier 2 and/or around the coupling element 8 are removed with the aid of etching processes. Additionally, the piezoelectric
25 element 5 can also be formed together with the carrier 2 and/or the coupling element 8 with the aid of the layering method.

Moreover, the at least one piezoelectric element 5 and the coupling element 8, together, form a cantilever arm 9 clamped on one side. The cantilever arm
30 9 comprises a clamped end 10, formed by the first end 6 of the piezoelectric element 5, and a free end 11 formed by the coupling element 8. The piezoelectric element 5, together with the coupling element 8, can form a

cantilever, which is connected to the carrier 2 at the clamped end 10. The free end 11 of the cantilever arm 9 can oscillate freely when it is connected exclusively to the diaphragm 3. In particular, the free end 11 has no connection to the carrier 2 and/or to the first oppositely positioned piezoelectric element 5. The free end 11 is decoupled with respect to the carrier 2. As a result, the free end 11 can oscillate freely. The free end 11 is not impeded with respect to the oscillation. As a result, the free end 11 can be deflected to a great extent, so that sound waves having a high amplitude can be generated and/or detected.

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In addition, a high linearity is established as a result. The amplitude of the electrical signal can be converted into a linearly proportional amplitude of the sound waves. The same applies when the MEMS sound transducer 1 is operated as a microphone. In that case, the amplitude of the sound waves can be converted into a linearly proportional electrical signal. Furthermore, with the aid of the cantilever arm 9, the diaphragm 3 can be deflected with the aid of a great force, since the free end 11 can move unimpeded.

Furthermore, the coupling element 8 can be arranged at the piezoelectric element 5 with the aid of an articulated joint 14a, 14b, which can be elastically formed. Additionally or alternatively, the articulated joint 14a, 14b can also be flexible. With the aid of the articulated joint 14a, 14b, during the deflection of the cantilever arm 9 along the reciprocation axis 4, the coupling element 8 can be rotated with respect to the piezoelectric element 5, so that the coupling element 8 can remain oriented in parallel to the diaphragm 3. The articulated joint 14a, 14b is preferably formed from at least one flexible and/or elastic connecting element. Preferably, the piezoelectric element 5 is formed from multiple layers, in particular at least one piezoelectric layer, one carrier layer, and/or one electrode layer. The at least one connecting element is preferably formed from one of these layers, in particular from the carrier layer.

Furthermore, according to the present exemplary embodiment from figure 1, the MEMS sound transducer 1 can comprise an open area 12, in a side view, between the side of the coupling element 8 facing away from the piezoelectric element 5, and the carrier 2. With the aid of the open area 12, 5 the cantilever arm 9 can oscillate freely.

Moreover, the carrier 2 comprises a recess 13, in which the cantilever arm 9 is arranged. In the present exemplary embodiment, the recess 13 is completely bordered by the carrier 2. Furthermore, the recess 13 extends 10 completely through the carrier 2 in the direction of the reciprocation axis 4.

In the description of the following exemplary embodiments, identical reference numerals are utilized for features that are identical or at least comparable in terms of their design and/or mode of operation as compared to 15 the preceding exemplary embodiments. Provided these features are not explained in detail once again, their design and/or mode of operation correspond(s) to the design and mode of operation of the features already described above.

20 Figure 2 shows a lateral sectional view of the MEMS sound transducer 1 as shown, for example, in figure 1. In this case, the diaphragm 3 is arranged on the carrier 2. In the present exemplary embodiment, the diaphragm 3 is arranged on a support element 15, which is connected to the carrier 2. Furthermore, the diaphragm 3 can be clamped on the support element 15. As 25 a result, the support element 15 can form a frame for the diaphragm 3.

Moreover, the diaphragm 3 can be arranged in the area of a top side 21 of the MEMS sound transducer 1. Furthermore, the MEMS sound transducer 1 comprises an underside 20 positioned opposite the top side 21. According to 30 the present exemplary embodiment, the piezoelectric element 5 can be arranged in the area of the underside 20. Consequently, the coupling

element 8 extends from the piezoelectric element 5 from the underside 20 to the diaphragm 3 at the top side 21.

According to the present exemplary embodiment, the MEMS sound
 5 transducer 1 comprises a coupling plate 16, which is arranged between the coupling element 8 and the diaphragm 3 and couples these to one another. The coupling plate 16 is arranged in the area of the top side 21 of the MEMS sound transducer 1. With the aid of the coupling plate 16, a planar force transmission between the coupling element 8 and the diaphragm 3 is
 10 established.

Figure 3 shows one further exemplary embodiment of a MEMS sound transducer 1 comprising two cantilever arms 9a, 9b. Each of the two cantilever arms 9a, 9b comprises a coupling element 8a, 8b, respectively,
 15 and a piezoelectric element 5a, 5b, respectively. The open area 12 is arranged between the two coupling elements 8a, 8b. The two cantilever arms 9a, 9b are decoupled from one another. The two cantilever arms 9a, 9b are connected only to the diaphragm 3. According to the present exemplary embodiment, assigned to each coupling element 8a, 8b is a coupling plate
 20 16a, 16b, respectively, which connects the coupling element 8a, 8b, respectively, to the diaphragm 3.

Furthermore, the two cantilever arms 9a, 9b are oriented opposite to each other. The two free ends 11a, 11b of the two cantilever arms 9a, 9b,
 25 respectively, face one another. The two cantilever arms 9a, 9b are connected to one another only via the diaphragm 3. The two cantilever arms 9a, 9b are arranged one behind the other in this case. "Arranged one behind the other" can mean, in this case, that the at least two cantilever arms 9a, 9b are merely offset with respect to one another in a translatory manner in a
 30 transverse direction of the MEMS sound transducer 1. The at least two cantilever arms 9a, 9b can be arranged, for example, on a line.

The MEMS sound transducer 1 of the exemplary embodiment from the present figure 3 comprises the recess 13 in which both cantilever arms 9a, 9b are arranged.

- 5 Figure 4 shows one further exemplary embodiment of a MEMS sound transducer 1 comprising two identically oriented cantilever arms 9a, 9b. The MEMS sound transducer 1 can comprise two recesses 13a, 13b, wherein one cantilever arm 9a, 9b is arranged in one recess 13a, 13b, respectively. The two recesses 13a, 13b are separated from one another by a middle
- 10 piece 17 of the carrier 2. The second cantilever arm 9b is arranged at the middle piece 17. The first cantilever arm 9a and the second cantilever arm 9b are aligned identically with respect to one another and/or are oriented identically with respect to one another. However, the first cantilever arm 9a and the second cantilever arm 9b are offset with respect to one another in a
- 15 translatable manner in the transverse direction of the MEMS sound transducer 1. The two cantilever arms 9a, 9b are arranged one behind the other in this case. "Arranged one behind the other" can mean, in this case, that the at least two cantilever arms 9a, 9b are merely offset with respect to one another in a translatable manner in a transverse direction of the MEMS sound
- 20 transducer 1. The at least two cantilever arms 9a, 9b can be arranged, for example, on a line. Therefore, they have the same freedom of movement with respect to one another, but engage the diaphragm 3 in different areas, which are offset with respect to one another in a translatable manner.
- 25 The diaphragm 3 extends beyond the middle piece 17. According to the present exemplary embodiment from figure 4, a gap 18 is formed between the middle piece 17 of the carrier 2 and the diaphragm 3 in the neutral position of the diaphragm 3. The diaphragm 3 is therefore spaced apart from the middle piece 17 of the carrier 2. Consequently, the diaphragm 3 is
- 30 decoupled from the middle piece 17. In the present case, the carrier 2 is designed to be precisely as thick in the area of the middle piece 17 as in its edge area. Alternatively, the middle piece 17 could also be designed to be

thinner than the edge area, so that the gap 18 or the distance between the diaphragm 3 and the middle piece 17 is enlarged (cf. figure 7). Alternatively, the diaphragm 3, in its neutral position, could also rest loosely on the middle piece 17, however. In one alternative exemplary embodiment, the diaphragm
 5 3 can also be connected, in particular adhered, to the middle piece 17 of the carrier 2, however.

With the aid of the two cantilever arms 9a, 9b, the diaphragm 3 can be deflected to an even greater extent. In addition, the diaphragm 3 can be
 10 deflected with the aid of a greater force and uniformly in a planar manner.

Figure 5 shows one further exemplary embodiment of a MEMS sound transducer 1, in a top view, comprising two cantilever arms 9a, 9b. The two cantilever arms 9a, 9b are adjacently arranged and identically oriented.
 15 Moreover, the two cantilever arms 9a, 9b comprise longitudinal sides 19a – 19d, which are parallel to one another. The first longitudinal side 19a of the first cantilever arm 9a as well as the second longitudinal side 19d of the second cantilever arm 9b face the carrier 2 and are spaced apart therefrom. The second longitudinal side 19b of the first cantilever arm 9a and the first
 20 longitudinal side 19c of the second cantilever arm 9b face one another and are spaced apart from one another. The open area 12 is therefore arranged around the particular cantilever arm 9a, 9b in a U-shaped manner. The open area 12 therefore has, in this top view from Figure 5, a U-shape around a particular cantilever arm 9a, 9b. The open area 12 around both cantilever
 25 arms 9a, 9b has a W-shape.

The two cantilever arms 9a, 9b have no direct connection to one another. The two cantilever arms 9a, 9b are decoupled from one another. The two cantilever arms 9a, 9b are both connected only to the diaphragm 3.

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With the aid of the arrangement of the cantilever arms 9a, 9b adjacent to one another and the arrangement one behind the other, the multiple cantilever

arms 9a, 9b can be arranged in a planar manner. At least three cantilever arms 9 are necessary for this purpose. For example, two cantilever arms 9a, 9b can be arranged according to the exemplary embodiment shown here and at least one further cantilever arm can be arranged behind one of the two

5 cantilever arms 9a, 9b. As a result, at least two cantilever arms 9 are arranged one behind the other. The three cantilever arms 9 can then be arranged in the geometric figure of a right triangle, wherein one cantilever arm 9 is in a corner of the right triangle in each case. As a result, the diaphragm 3 can be deflected in a planar manner. The three cantilever arms

10 9 can also be arranged in an isosceles or equilateral triangle, however.

Alternatively, cantilever arms can also be arranged in another geometric figure, wherein the number of corners of the geometric figure corresponds to the number of cantilever arms. For example, four cantilever arms can be

15 arranged in a square, a rectangle, a trapezoid, a rhombus, or an irregular quadrilateral.

Figure 6 shows one further exemplary embodiment of a MEMS sound transducer 1 comprising a cantilever arm 9, which includes two piezoelectric

20 elements 5a, 5b and one coupling element 8. The two piezoelectric elements 5a, 5b are adjacently arranged and oriented identically to one another. In the area of its two ends 7a, 7b, the two piezoelectric elements 5a, 5b are connected to one another with the aid of a coupling element 8. As a result, the diaphragm 3 can be deflected with the aid of a great force.

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The first longitudinal side 19a and the second longitudinal side 19b of the cantilever arm 9 are each spaced apart from the carrier 2. The open area 12 is designed to be U-shaped in this case and extends around the cantilever arm 9. As a result, the free end 11 of the cantilever arm 9 can deflect freely

30 along the reciprocation axis 4.

Figure 7 shows one further exemplary embodiment of a MEMS sound transducer 1, which comprises two cantilever arms 9a, 9b. The two cantilever arms 9a, 9b are oriented identically with respect to one another, wherein the second cantilever arm 9b is arranged at the middle piece 17 of the carrier 2.

5 In the present exemplary embodiment, the two coupling elements 8a, 8b of the two cantilever arms 9a, 9b, respectively, are connected to the diaphragm 3 with the aid of the same, in particular single, coupling plate 16. As a result, the diaphragm 3 can be synchronously deflected by both cantilever arms 9a, 9b. The coupling plate 16 extends in the transverse direction of the MEMS

10 sound transducer 1 over the first coupling element 8a as well as over the second coupling element 8b.

The gap 18, according to the present exemplary embodiment, is greater than the gap 18 from figure 4. For this purpose, the middle piece 17 is designed to

15 be thinner than the edge area of the carrier 2. The gap 18 is preferably approximately one half of a thickness of the edge area of the carrier 2 in the direction of the reciprocation axis 4. As a result, the diaphragm 3 can deflect to a great extent in the direction of the middle piece 17, without impacting the middle piece 17. Alternatively, however, the middle piece 17 can also extend

20 up to the coupling plate 16, so that the coupling plate 16 rests loosely on the middle piece 17 in the neutral position of the diaphragm 3. The middle piece 17 can therefore also be precisely as thick as the edge area of the carrier 2. The rigid coupling plate 16 extending over the middle piece 17 is decoupled from the middle piece 17, however, in particular being spaced apart

25 therefrom in the neutral position of the diaphragm 3.

Additionally, the two cantilever arms 9a, 9b can also comprise the articulated joint 14a – d (not shown here) or connecting elements. As a result, the coupling elements 8a, 8b of the cantilever arms 9a, 9b, respectively, can

30 rotate with respect to the corresponding piezoelectric elements 5a, 5b, so that, during the deflection of the diaphragm 3, the coupling elements 8a, 8b remain aligned in parallel to the diaphragm 3.

The cantilever arms 9a, 9b are arranged one behind the other in this case. The at least two cantilever arms 9a, 9b can therefore be arranged on a line. In one alternative exemplary embodiment, multiple, for example, three, four,
 5 cantilever arms 9 can also be arranged one behind the other, in particular on a line. Additionally, at least one cantilever arm 9 can also be arranged adjacent to at least one of the cantilever arms 9a, 9b shown here. Two adjacently arranged cantilever arms 9a, 9b are shown, for example, in figure 5.

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Figure 8 shows one further exemplary embodiment of a MEMS sound transducer 1. A spacer element 22a, 22b is arranged between the diaphragm 3 and the two coupling elements 8a, 8b, respectively, of this exemplary embodiment. The spacer elements 22a, 22b can have, in the direction of the
 15 reciprocation axis 4, a thickness comparable to the carrier 2 and/or to the support element 15. In particular, a sum of the thicknesses of the spacer elements 22a, 22b and a thickness of the coupling plate 16 can correspond to the thickness of the support element 15. The spacer elements 22a, 22b can be adhesively bonded onto the coupling elements 8a, 8b, respectively,
 20 for example, after a process of manufacturing the coupling elements 8a, 8b. Due to the spacer elements 22a, 22b, for example, the volumes of the open areas 12a, 12b and of the recesses 13a, 13b can be enlarged. As a result, acoustic properties of the MEMS sound transducer 1 can be adjusted.

25 Furthermore, according to figure 8, the gap 18 is arranged between the middle piece 17 and the diaphragm 3 and is widened due to the fact that the spacer elements 22a, 22b are arranged between the diaphragm 3 and the coupling elements 8a, 8b, respectively.

30 In this case as well, multiple cantilever arms 9a, 9b can once again be arranged adjacent one another, as shown, for example, in figure 5 and as described with respect thereto. The two cantilever arms 9a, 9b shown here

are arranged one behind the other again. Multiple cantilever arms 9a, 9b can also be arranged one behind the other, however.

The present invention is not limited to the represented and described
5 exemplary embodiments. Modifications within the scope of the claims are also possible, as is any combination of the features, even if they are represented and described in different exemplary embodiments.

List of reference numerals

	1	MEMS sound transducer
	2	carrier
5	3	diaphragm
	4	reciprocation axis
	5	piezoelectric element
	6	first end
	7	second end
10	8	coupling element
	9	cantilever arm
	10	clamped end
	11	free end
	12	open area
15	13	recess
	14	articulated joint
	15	support element
	16	coupling plate
	17	middle piece
20	18	gap
	19	longitudinal side
	20	underside
	21	top side
	22	spacer element
25		

Claims

1. A MEMS sound transducer (1), in particular for generating and/or
 5 detecting sound waves in the audible wavelength spectrum,
 comprising
 a carrier (2),
 a diaphragm (3), which is connected to the carrier (2) and is
 deflectable with respect thereto along a reciprocation axis (4a, 4b),
 10 at least one piezoelectric element (5a, 5b) for generating and/or
 detecting a deflection of the diaphragm (3), which is spaced apart from
 the diaphragm (3) in the direction of the reciprocation axis (4),
 which comprises a first end (6a, 6b) connected to the carrier (2) and a
 second end (7a, 7b) deflectable in the direction of the reciprocation
 15 axis (4a, 4b), and
 a coupling element (8a, 8b),
 which extends in the direction of the reciprocation axis (4a, 4b)
 between the piezoelectric element (5a, 5b) and the diaphragm (3) and
 connects the second end (7a, 7b) of the piezoelectric element (5a, 5b)
 20 to the diaphragm (3),
 wherein the at least one piezoelectric element (5a, 5b) and the
 coupling element (8a, 8b), together, form a cantilever arm (9a, 9b)
 clamped on one side,
 which comprises a clamped end (10a, 10b), which is formed by the
 25 first end (6a, 6b) of the piezoelectric element (5a, 5b), and a free end
 (11a, 11b) formed by the coupling element (8a, 8b), wherein the MEMS
 sound transducer (1) comprises multiple cantilever arms (9a, 9b),
characterized in that
 the at least two cantilever arms (9a, 9b), in a top view, are arranged
 30 one behind the other.

2. The MEMS sound transducer as claimed in the preceding claim,
characterized in that the cantilever arm (9a, 9b) is connected, in the
area of its free end (11a, 11b), exclusively to the diaphragm (3).
3. The MEMS sound transducer as claimed in at least one of the
5 preceding claims, characterized in that an open area (12) is formed, in
a side view, between the side of the coupling element (8a, 8b) facing
away from the piezoelectric element (5a, 5b), and the carrier.
4. The MEMS sound transducer as claimed in at least one of the
preceding claims, characterized in that the open area (12) has a U-
10 shape, in a top view, so that the cantilever arm (9a, 9b) is spaced
apart from the carrier (2) at its free end (11a, 11b) and at both of its
longitudinal sides (19a – d).
5. The MEMS sound transducer as claimed in at least one of the
preceding claims, characterized in that the carrier (2) comprises at
15 least one recess (13) in which the cantilever arm (9a, 9b) is arranged,
wherein the recess (13) is preferably completely bordered by the
carrier (2).
6. The MEMS sound transducer as claimed in at least one of the
preceding claims, characterized in that a single cantilever arm (9a, 9b)
20 is arranged in the recess (13).
7. The MEMS sound transducer as claimed in at least one of the
preceding claims, characterized in that the MEMS sound transducer
(1) comprises multiple cantilever arms (9a, 9b), which, in a top view,
are arranged laterally adjacent to one another.
- 25 8. The MEMS sound transducer as claimed in at least one of the
preceding claims, characterized in that at least two cantilever arms

(9a, 9b) are oriented identically and/or oppositely with respect to one another.

9. The MEMS sound transducer as claimed in at least one of the preceding claims, characterized in that at least two adjacently
5 arranged and identically oriented cantilever arms (9a, 9b) are connected to each other in the area of the free end (11a, 11b) with the aid of a coupling element (8a, 8b).
10. The MEMS sound transducer as claimed in at least one of the preceding claims, characterized in that the coupling element (8a, 8b)
10 is connected to the piezoelectric element (5a, 5b) with the aid of an, in particular elastic or flexible, articulated joint (14a – d), so that the coupling element (8a, 8b) is rotatable in relation to the piezoelectric element (5a, 5b).
11. The MEMS sound transducer as claimed in at least one of the preceding claims, characterized in that the piezoelectric element (5a,
15 5b) and the coupling element (8a, 8b) are formed from the same material.
12. The MEMS sound transducer as claimed in at least one of the preceding claims, characterized in that the MEMS sound transducer
20 (1) is a MEMS loudspeaker and/or a MEMS microphone.