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Tunable MEMS Device

Field of the Invention

The present invention relates to microelectromechanical systems (MEMS) devices which comprise a piezoelectric element or material.

Background of the Invention

MEMS devices are increasingly being used as sensors, actuators, transducers, and even filters. The technology surrounding MEMS is becoming increasingly reliable, cost effective, and enabling of miniaturisation. Numerous MEMS devices forming sensors, actuators and transducers have been demonstrated based on electrostatic operating principles, such as described in U.S. 6269698 and U.S. 6248610 for example. However, it is difficult to design and manufacture high sensitivity electrostatic devices, and such devices require a high D.C. bias voltage and are restricted to particular geometrical configurations which provide the necessary electrical gap.

Piezoelectric thin films can be used for MEMS devices to provide greater sensitivity than electrostatic devices. An example of a MEMS device based on piezoelectric thin film materials is shown in U.S. 5914507 which discusses a sensor/actuator device having a deflectable piezoelectric component. The deflectable component is movable with applied voltage to enable operation as an actuator, for example as a micromechanical valve or pump.

Tunable MEMS devices are useful as filters particular for high frequency applications such as those required in mobile phones, and an example of such a device is shown in U.S. 5729057. However this is an electrostatic based device and for high resonant frequencies only a small amount of frequency tuning can be realised with electrostatic tuning due to the applied force limitation with limited electric gaps. An adjustable surface acoustic wave (SAW) transducer is shown in U.S. 6291924 in which switches are used

to provide a plurality of interconnection patterns between the SAW IDT fingers such that a plurality of SAW characteristics can be generated from a single set of fingers. However the response time of this arrangement is slow.

Summary of the Invention

It is an object of the present invention to provide an improved or alternative tunable MEMS device.

In general terms, the present invention proposes that a MEMS device includes a resonant member having a section of piezoelectric material. A control circuit controls electric fields applied to the piezoelectric material, to vary the frequency and/or the quality factor of the resonance.

Specifically, a first aspect of the invention provides a MEMS device having:

a substrate;

a resonant member having a portion fixed to said substrate and another portion being free to move, the resonant member having a resonant frequency of said movement;

at least one section of piezoelectric material located on the resonant member;

at least two electrodes disposed on the resonant member, and for applying an electric field to at least part of the piezoelectric material, and

a control circuit in electrical contact with electrodes, and for controlling the electrodes to apply an electric field to at least part of said piezoelectric material in order to adjust at least one characteristic of said resonance.

In a second aspect, the invention provides a method of controlling the resonance of a resonant member of a MEMS device, the resonant member

having a portion supported by a substrate and another portion being free to move, there being at least one section of piezoelectric material located on the resonant member, the method including controlling electrodes to apply an electric field to at least part of said piezoelectric material in order to adjust at least one characteristic of said resonance.

Brief Description of the Drawings

Non-limiting embodiments of the invention will now be described with reference to the following drawings in which;

Fig 1, is composed of Figs. 1(a) and 1(b) showing cross-sectional and plan views respectively of a first embodiment tuneable MEMS device according to the invention;

Fig. 2 shows the fundamental vibration mode for a beam/plate structure;

Fig. 3 shows passive tuning of the embodiment for modifying the structural resonant frequency;

Fig. 4 shows active tuning of the embodiment for modifying the structural resonant frequency;

Fig. 5 shows an implementation in which modifying the structural resonant frequency is achieved by modal coupling;

Fig. 6 shows an embodiment in which the structural Q is modified using active tuning;

Fig. 7 is composed of 7a and 7b respectively showing frequency tuning and Q tuning;

Fig. 8 shows a third embodiment of the invention which includes two piezoelectric beams/plates;

Fig. 9 shows a modification to the third embodiment tuneable MEMS device which includes a resonant piezoelectric beam/plate, and two piezoelectric tuning beams/plates;

Fig. 10 shows a further modification to the third embodiment tunable MEMS device which includes a resonant piezoelectric beam/plate, two tuning piezoelectric beams/plates, and two additional piezoelectric supporting beams/plates.

Fig. 11 shows a process flow chart for fabrication of a tunable PZT MEMS device;

Fig. 12 shows a second flow chart of a process for fabrication of a tunable PZT MEMS device;

Fig. 13 shows a modification to the first embodiment tuneable MEMS device for out-of-plane acceleration sensing;

Fig 14 is composed of Figs. 14a and 14b showing a fourth embodiment of the invention for in-plane acceleration sensing;

Fig. 15 shows a further embodiment tuneable MEMS device applied as a microphone;

Fig. 16 shows a modification to the embodiment tuneable MEMS device applied as a microphone;

Fig. 17 is a further embodiment tuneable MEMS device consisting of an in-plane beam/plate array;

Fig. 18, which is composed of Figs. 18(a) to 18(f), schematically shows the tuneable MEMS device of Fig. 17 applied as either a bandpass or notched filter;

Fig. 19 is a schematic of the tuneable MEMS device of Fig. 17 applied as an adaptive filter;

Fig. 20 shows a further embodiment tuneable MEMS device which consists of in-plane beam/plate batch array;

Fig. 21 shows a modification of the embodiments of Figs. 17 and 20 which consists of in-plane beam/plate array plus tuning beam elements;

Figs. 22a and 22b show a further embodiment tuneable MEMS device which consists of a clamped-free in-plane beam/plate array and proofed masses.

Detailed Description of the Invention

The invention will be described by reference to figures which illustrate: firstly, a first illustrative embodiment of the invention (Figs. 1 and 2); the operating principle of the illustrated embodiment of the invention (Figs. 3 to 7); two alternative illustrative embodiments (Figs. 8 to 10); methods of fabricating embodiments of the invention (Figs. 11 and 12); and finally how embodiments of the invention may be selected for specific MEMS applications (Figs. 13 to 22).

Specifically, Figures 1(a) and 1(b) show respectively cross-sectional and plan views of a tunable MEMS device 10 according to a first embodiment of the present invention. The cross-section of Fig. 1(a) is in the direction shown as B-B in Fig. 1(b). The device 10 comprises two substrate mounts 15a and 15b, between which is mounted a support structure 14 which is fixed at each end to one of the substrate mounts 15a or 15b. A metal film "bottom" electrode 13 is mounted on the support structure 14. A piezoelectric thin film or layer 12 is mounted on the bottom electrode 13, and three "top" electrodes 11a, 11b, and 11c are mounted on the piezoelectric layer 12. These electrodes 11a, 11b and 11c are coplanar and together define a layer referred to here as layer 11. Two longitudinally extending cut outs 16 through the layers 11, 12, 13 and 14

of the device 10 are arranged to define a narrow beam or resonant member 17. The member 17 is free to move out-of-plane in the direction indicated by A, although the two ends are constrained by the fixings to the substrate mounts 15a or 15b. The modes of vibration of the member 17 are shown in figure 2.

Various alternative structural arrangements are possible, for example the support structure 14 may be fixed to only one substrate mount 15a to form a cantilevered structure. A cantilevered structure is preferred for low frequency applications such as microphones for example, whilst a bridge structure as shown in Figure 1 having the support structure 14 fixed or clamped at both ends to the substrate mounts 15a and 15b is preferred for high-frequency applications such as RF filters for mobile phones for example. Also whilst the preferred arrangement of the layers (11, 12, 13, 14) is as shown in Figure 1, alternative arrangements or sequences of the various layers could be used. Similarly, while three top electrodes 11a, 11b and 11c are preferably used in the device 10, a single or multiple top electrodes 11 may alternatively be used. Apertures in the layer 12 define contact points 18a, 18b with the electrode 13, while the electrodes 11a, 11b, 11c have respective contact electrodes 19a, 19b, 19c.

Preferably the substrate mounts 15a and 15b are typically of silicon (although other materials are also possible), the support structure 14 is typically silicon dioxide, silicon, polysilicon, or SiN (although again other materials, such as metals, are also suitable), and the bottom 13 and top 11 electrodes are of a suitable conductor (e.g. the bottom electrode 13 may be of Pt/Ti as described below, and the top electrode 11 of Pt). Preferably the piezoelectric material is lead zirconate titanate (PZT) or PZT-PMN, although other piezoelectric materials could be used, for example zinc oxide and aluminium nitrate.

The fundamental resonant frequency w_n of the clamped member 17 can be expressed as follows when it is subjected to an axial force F;

$$w_n = \frac{1}{2\pi}\left(\frac{4.73}{l}\right)^2\sqrt{\frac{EI}{pA}\left(1+0.295\frac{Fl^2}{12EI}\right)} \quad , \qquad (1)$$

where l is the member 17 length, A is its cross-sectional area, p is its density, E is the effective elastic modulus, and I is the effective moment of inertia. The resonant frequency of the member 17 is adjusted by adjusting the axial force F. This is achieved by the application of electric fields to the piezoelectric layer 12 using the top and bottom electrodes 11a, 11b, 11c and 13, to generate in plane compression or expansion and thus generate a tension in the member 17. Thus when D.C. bias electric fields are added to the top electrodes 11a and 11c, in-plane tension or compression loads will be generated. These loads modify the flexural rigidity of the member 17, which in turn affects its resonant frequency w_n. By adjusting the D.C. bias fields, the piezoelectric MEMS device 10 becomes frequency tunable. Note that although in plane compression/expansion of the piezoelectric layer 12 is preferred as the mechanism for tuning the device 10, other deformations may alternatively or additionally be used, and in general any deformation of the piezoelectric layer 12 will affect the structural resonant frequency.

The areas of the piezoelectric layer 12 about each of the top electrodes 11a, 11b, and 11c define three piezoelectric active zones, referred to generally by x, y, and z respectively. Preferably these active zones are located at each end and in the middle part of the member 17, to enhance the degree of electromechanical coupling between the active piezoelectric layer 12 and the support structure 14 since these zones are located about the main stresses or strains associated with the fundamental vibration mode of the member 17. This fundamental vibration mode is shown in Figure 2, which is produced

using a finite element analysis. This technique is particularly useful for analysing and designing embodiments of the present invention, since it permits the strain at all points to be included in the calculation.

Note that many variations of this device are possible, employing the same working principle. For example, it is not necessary to have as many as three electrodes 11a, 11b and 11c, and in principle any number of electrode(s) can be used. Furthermore, in other embodiments, one or other any number of piezoelectric active zones are utilised, any one or more of which can be used to adjust the resonant frequency.

The piezoelectric active zones x, y, z whilst acting as tuning elements can also be used as inputs and/or outputs for the device 10. For example when used as a microphone, acoustic vibrations applied to the member 17 will move it in an out of plane direction A. This movement will cause contraction/expansion in the piezoelectric zones x, y, z which generate an electrical charge or voltage between a top electrode 11a, 11b, 11c and the bottom electrode 13 which can be detected.

We turn now to a discussion of how the device 10 of Fig. 1 is tuned. This may be by passive tuning, or by active tuning.

The case of passive tuning is shown in Fig. 3, where a voltage supply 20a is used to generate a variable DC voltage bias between contacts 18a and 19b, and a voltage supply 20b is used to generate a variable voltage difference which is applied between contacts 18b and 19c. The variable voltage biases permit tuning the centre frequency of the resonance of the member 17.

The case of active tuning is illustrated in Fig. 4, where a reference/excitation signal is applied to the device 10 as a voltage difference between contacts 18b and 19c. This produces vibrations in the member 17 which in turn

generate voltages across the piezoelectric material. The frequency components in the voltage at contact 19b are detected by a frequency detection unit 122, which provides an input for a controller 123, which in turn provides an input for a driver 124, which outputs a voltage to contact 19a. This makes it possible to adjust the frequency characteristics of the member 17 "online", i.e. using a comparison of the measured frequency of the vibrations of the member 17 with a desired frequency. The contact 18a is simply connected to ground. Note that the many variations of the arrangement of Fig. 4 are possible in which the contacts 18a, 18b, 19a, 19b and 19c to different ones of the active components 121, 122, 123, 124.

Referring to Fig. 5 a variation 110 of the embodiment of Fig. 1. In device 110 the electrode 11b is replaced by two electrodes 11d, 11e, having corresponding contacts 19d, 19e. An excitation element 161 generates a signal to contact 19c, and a signal is generated at contact 19e, which is sensed by a sensing unit 162. As in Fig. 4, a signal at contact 19d is detected by a frequency detection unit 163, and this is provides a signal for a frequency synthesiser 164, which in turn provides a signal to the driver 165, which outputs a signal to the contact 19a. Thus there are two sets of excitation/detection units: units 161 and 162; and units 163, 164, and 165. The first operates as a resonator with fixed resonant frequency, while the second is used as a tuner, which may both excite and sense structure resonance with other different modes. As is known from structural dynamics, the modal coupling may change the desired centre frequency of the PZT micromechanical device 110.

Since in the devices 10, 110 distributed piezoelectric active zones are formed on the surface of the member 17, either active tuning or passive tuning can be used to modify the structural Q value as well as the centre frequency. A high

structural Q provides high selectivity of frequencies about the resonant frequency, but only a narrow bandwidth, and vice versa.

An example of active tuning to achieve this is shown in Fig. 6, in which the device 10 is again used. Again, a reference/excitation unit 211 is connected between contacts 18b and 19c. Contact 19b provides a signal which is input to amplifier 212, which sends its output to amplitude detection unit 213, which sends an output to controller 214, which sends its output to driver 215, which in turn sends its output to the contact 19a. Control is applied from outside using the controller 214.

Alternatively, the structural Q factor may be controlled by passive tuning by connecting the device 10 to a passive circuit which includes any of resistors, resistors/inductors or resistors/inductors/capacitors. Such arrangments may exploit the fact that the deposited piezoelectric film 12 itself has a capacitance. The exact realisation of circuits which do this would be well known to a skilled person.

Fig. 7 is composed of Figs. 7(a) to 7(c). Fig. 7(a) shows the amplitude of vibration of the member 17 in the absence of tuning according to the invention. It has an effective bandwidth *a*, between frequencies f_{e1} and f_{e2}, but its desired bandwidth is *b*, between frequencies f_{d1} and f_{d2}. Frequency tuning is shown in Fig. 7(b), so that the effective bandwidth of the device is increased to *c* between f_{e1} and f_{e2}. Fig. 7(c) shows an example of Q tuning. In the absence of the invention, the frequency response is as shown in line 150, but the present invention makes it possible for Q to be increased so that the frequency response becomes the wider one shown as line 250.

Fig. 8 shows a further embodiment in which the tuning is provided by a separate structural element from the resonant member. The device 300

comprises a resonant member 307 which has two top electrodes 301a and 301b which each act as either an input or an output. The device 300 further comprises a tuning structure generally referred to as 320 which comprises a tuning member 327 having two top electrodes 321a and 321b. Both the resonant member 307 and the tuning member 327 have the same layer structure as the resonant member 17 described with respect to the first embodiment of Fig. 1. Contacts 303, 304 are in electrical contract with respective electrode layers (not shown) in the resonant member 307 and tuning member 327. Each member 307 and 327 is fixed at one end to a substrate mount (15a and 15b in Fig. 1) and are coupled together at their other free ends 328.

In the tuning member 327, the top electrodes 321a and 321b provide electric fields which act on the underlying piezoelectric material to twist the tuning member as shown by arrows M. This has the effect of expanding or contracting the resonant member 307 and hence altering its resonant frequency w_n. Thus an input signal at electrode 301a may be filtered by the resonant member 307 to provide a filtered output signal at electrode 301b. The centre frequency of the filter is adjusted by twisting tuning member 327 by the application of appropriate electric fields.

Figs. 9 and 10 show modified versions of the embodiment of Fig. 8. In Fig. 9, two tuning members 427, 437 are used to apply tension to a resonant member 407. Having two tuning members 427, 437 enables the generation of a larger axial force F in the resonant member 407, and hence increases the tuning range of the device. The arrangement of Fig. 10 is similar to that of Fig. 9, but additional supporting plates 429 and 439 are provided extending between the resonant member 407 and the supporting frame 415, connected to the resonant member 407 to support it.

The above described tuneable MEMS devices are easy to fabricate, not requiring the narrow electrode gap of electrostatic based MEMS devices. Figs. 11 and 12 illustrate processes for producing devices according to the embodiments of the invention.

In Fig. 11, at step (i) the starting wafer is fabricated by depositing a dielectric layer, preferably SiO_2, on the Si substrate. In step (ii), a sputtered adhesion layer like Ti is then deposited on top of the oxide, followed by a sputtered bottom electrode like Pt that covers the entire structure. The piezoelectric material, preferably PZT, is deposited on the bottom electrode in step (iii) until the desired thickness is achieved. Either sputtering, CVD, PVD or sol-gel methods may be used to form the PZT thin film. The top electrode is deposited on the entire PZT surface in step (iv). After all film deposition is complete, masks are used to pattern the top electrode, the PZT and other layers to obtain the opening in step (v). Either selective wet etching, ion milling or isotropic silicon etching may be used in micromachining, as shown in steps (vi) and (vii). Finally, the beam is freed in step (viii).

An alternative process is illustrated in Fig. 12, in which surface micromachining is mainly used. In step (i) there is a deposition and patterning of a sacrificial layer of Si, in step (ii) the deposition of a support layer, in step (iii) the deposition of a dielectric layer, in step (iv) the deposition of Pt/Ti to form the bottom electrode, in step (v) the deposition of the PZT layer and the top electrode, in step (vi) the patterning of the top electrode, in step (vii) etching of the PZT layer, in step (viii) the etching of the sacrificial layers, and in step (ix) the etching of the sacrificial layers and the freeing of the beam. The method of Fig. 12 is compatible with conventional IC fabrication techniques. This provides the possibility of the formation of an embodiment of the invention as an on-chip component including the piezoelectric MEMS device and associated electronics.

We now turn to embodiments of the invention for use in specific technical situations.

Firstly, let us consider the situation of using such as embodiment as a sensor. The embodiment of Fig. 1 is suitable for this purpose. Referring to Fig. 1 the out of plane bending of the member 17 will induce an inertial force to deflect and strain the resonant beam, which in turn shifts its resonant frequency according to equation (1). Measurements of the resonant frequency thus give an indication of an acceleration experienced by the device 10. Fig. 13 shows a modification to the member 17 of the first embodiment of Fig. 1 in which additional member mass 117 is disposed on it near the central electrode 11b. This increases the sensitivity of the device 10 when used as a force sensor or accelerometer. This is because more applied force is required to bend the member 17 and hence adjust its resonant frequency.

Fig. 14a shows a variation of the embodiments of Figs. 9 and 10, which can be used as an accelerometer. The accelerometer 500 has a resonant member 507, supported by two support members 509a, 509b. It measures acceleration in the in-plane direction which induces an inertial axial force F in the member 507 to extend/compress the member, which in turn changes its resonant frequency and which is detectable as described above.

Fig. 14b shows a modification 510 to this arrangement in which a proofed mass 511 is added to increase the sensitivity of the device 510. Note that both arrangements have the resonant member 507 fixed at only one end to form a cantilever structure. An accelerometer utilising the above described resonant concept is superior to conventional electrostatic accelerometers in sensitivity, dynamic range, and disturbance resistance. Since any applied force or temperature may deflect/strain the resonant member 507, which in turn shifts

its resonant frequency, the MEMS device of the present invention may be implemented as a force/temperature sensor. Also since a slight mass will shift the resonant frequency of the member, the devices may also be implemented as tuneable weight or mass sensors, for example in the fields of biomedical and chemical engineering.

Secondly, let us consider the use of embodiments of the invention as transducers. Fig. 15 shows a device according to the invention which is implemented as a tuneable microphone 600. Transducers like microphones are a kind of pressure sensor which may be used to detect air/waterborne sound pressures whose magnitudes are far lower than that of ambient pressure. Thus a microphone needs an extremely compliant diaphragm to have an acceptable sensitivity. In Fig. 15 a resonant member 607 is provided as a diaphragm, having a spring zone of reduced thickness to improve its flexibility to sound pressure. Either or both f or Q may be tuneable. Also a DC bias can be used to adjust the diaphragm geometry to increase the acoustic coupling effect. The outputs of electrodes 611b and 611c are fed to a first input of a differential amplifier 612, which receives the outputs of the electrodes 611a and 611b as its other input.

Fig. 16 shows an alternative implementation for a microphone having a different configuration of diaphragms 617 and top electrodes 621. Numerous other diaphragm arrangements are known in the art, and appropriate combinations of piezoelectric material and top electrodes are contemplated by the invention. As already discussed above, such devices could alternatively be used as microspeakers by the application of electrical signals to the top electrodes. Devices according to embodiments of the invention can usefully be employed as ultrasonic transducers due to the high frequency range and sensitivity of piezoelectric sensors.

Thirdly, we consider the use of embodiments of the invention as filters. In order to provide a wide bandwidth filter at high frequencies a further embodiment of the invention is described with reference to Fig. 17. This embodiment uses an array of resonant members 707 each at slightly differing centre frequencies such that together they provide a wide bandwidth filter. Each resonant member 707 is provided with four electrodes 711a, 711b, 711c, 711d, the output of electrodes 711a and 711d, and of electrodes 711b and 711c being combined. The centre frequency of each member 707 is shown as f_1, f_2, ..f_n. The electrodes a, b, c and d are used for exciting, sensing and tuning as described above with respect to other embodiments of the invention. The array of Fig. 17 includes resonant members 707 of differing lengths in order to cover a wide frequency range. Alternatively or additionally members having different widths and/or thicknesses may be used. A MEMS based filter having high f of GHz order and high Q is considered to have wide application in wireless communications devices such as mobile phones.

The device 700 may be configured as a bandpass or notch filter having a wide bandwidth and high Q as shown in Figs. 18(a) to 18(f). Fig. 18(a) shows schematically the multiple frequency components of an input signal. This frequency response is used via a modulator in Fig. 18(b), and the result is applied to an array such as device 700 which is controlled to adjust its frequency and Q response, as shown in Fig. 18(c). A modulator in 18(d) is used to revise signal gain further. The according to the frequency and Q tuning selected, the result may be that the device 700 functions as a basspass filter having a frequency response as shown in Fig. 18(e), or as a notched signal filter having the frequency response shown in Fig. 18(f).

As a further alternative the device 700 may be configured as an adaptive filter as shown in Fig. 19 for signal processing in parallel. A disturbance signal 801 is input and added to a reference signal 802. The result is input to a tunable

PZT micromechanical array 803 of resonant members (this array may be the device 700) to generate an output signal. The output is also fed to a processor 804, which uses it to control an adjuster/controller 805 which tunes each of the resonant members of the array of members 803 by the principles discussed above.

Thus, the embodiments of Figs. 18 and 19 provide signal processing "in parallel". The device 700 may thus be used to mitigate the effects of noisy environments when using mobile phones for example, in that the main frequency components of a persons voice are used as training samples or a reference. With adaptive signal processing the output signal may be adjusted to follow the reference value, which may by-pass the disturbance (or a noise) to improve the signal-to-noise ratio. The device could also be used for pattern matching in voice recognition systems, or feature based sound synthesisers with a microspeaker. An advantage of MEMS based signal processing over conventional methods is its compatibility with microelectronic technology, which results in miniaturisation, batch process and cost-effectiveness.

Note that the device 700 of Fig. 17 may be adapted as shown in Fig. 20 so that there are a plurality (a "batch") of resonant members 707 for each of the n frequencies. This is shown in Fig. 20 in the case that there are two members 707 for each batch.

The arrangement of Fig. 17 may alternatively be modified as shown in Fig. 21 to include tuning members 727 with the properties and advantages of the tuning members 327 described above with reference to Fig. 8. These increase the tuneable bandwidth of each resonant member 707's resonant frequency.

As a further alternative, each of a set of cantilevered resonant members 807 shown in Fig. 22(a) may be provided with a proofed mass 808.

The arrangement of cantilevered resonant members 807 may be as shown in Fig. 22b, where the resonant members 807 extend inwardly from either side of a frame 809. Different proofed masses 810 are added to each resonant member 807. This is especially useful for devices operating at low frequencies such as in the order of 100Hz, in order to maintain a relatively compact structure.

Features of the various embodiments are freely combinable with each other. Furthermore, many variations of the embodiments described above are possible within the scope of the invention as will be clear to a skilled reader.

CLAIMS

1. A MEMS device having:

a substrate;

a resonant member having a portion fixed to said substrate and another portion being free to move, the resonant member having a resonant frequency of said movement;

at least one section of piezoelectric material located on the resonant member;

at least two electrodes disposed on the resonant member, and for applying an electric field to at least part of the piezoelectric material, and

a control circuit in electrical contact with electrodes, and for controlling the electrodes to apply an electric field to at least part of said piezoelectric material in order to adjust at least one characteristic of said resonance.

2. A method according to claim 1 in which one said characteristic is the frequency of the resonance.

3. A method according to claim 1 or claim 2 in which one said characteristic is the quality factor Q of the resonance.

4. A MEMS device according to claim 1, claim 2 or claim 3 in which said electrodes comprise a first electrode layer located on the resonant member, and a second electrode layer, the first and second electrode layers sandwiching a layer of the piezoelectric material.

5. A MEMS devices according to any preceding claim in which the electrodes are arranged to apply said electric field to an area of said piezoelectric material proximate an area of the resonant member which experiences maximal stress in said resonance.

6. A MEMS device according to any preceding claim in which the resonant member is elongate and supported from one end as a cantilevered structure.

7. A MEMS device according to any preceding claim in which the resonant member is elongate and supported from both its ends.

8. A MEMS device according to any preceding claim, further comprising at least one sensor for to sense the vibration of the resonant member.

9. A MEMS device according to claim 8 in which said sensor senses the electric field within a part of said piezoelectric material.

10. A MEMS device according to claim 8 or claim 9 further comprising means to generate a reference vibration in said resonant member, an output of the sensor being transmitted to the control means.

11. A MEMS device according to claim 10 in which the output of the sensor is transmitted to the control means by a frequency detection device for detecting the amplitudes of different frequencies in the vibration.

12. A MEMS device according to any preceding claim further comprising a tuning member attached to the resonant member and means to deflect the tuning member to apply a strain to the resonant member.

13. A MEMS device according to any preceding claim in which the resonant member supports an element of known mass, the element of known mass influencing the frequency of the resonance.

14. A MEMS device according to any preceding claim in which there are a plurality of resonant members, including one or more members having each of a number of different resonant frequencies.

15. A MEMS device according to claim 14 in which there are a plurality of resonant members for each of said frequencies.

16. A MEMS device according to any preceding claim which is arranged as a sensor, having an output which is obtained from a signal generated by a vibration of the resonant member.

17. A MEMS device according to any of claims 1 to 15 which is a transducer.

18. A MEMS device according to any of claims 1 to 15 when dependent on claim 8 which is arranged as a filter, the device being arranged to receive a signal having multiple frequency components for which the device has different respective vibrational responses, and the sensor being arranged to detect the amounts of the different components.

19. A method of controlling the resonance of a resonant member of a MEMS device, the resonant member having a portion supported by a substrate and another portion being free to move, there being at least one section of piezoelectric material located on the resonant member, the method including controlling electrodes to apply an electric field to at least part of said

piezoelectric material in order to adjust at least one characteristic of said resonance.