CLAIMS

1. A method, comprising:

towing a streamer behind a survey vessel in a body of water, wherein the streamer includes an accelerometer;

detecting, by at least four capacitors within the accelerometer, a change in acceleration of the accelerometer,

wherein:

the four capacitors include a first capacitor and a second capacitor on a first side of a proof mass and a third capacitor and a fourth capacitor on a second side of the proof mass, and each of the four capacitors includes a respective pair of electrodes; and

in response to the proof mass moving in a selected direction, a capacitance of the first and second capacitors is operable to increase, and a capacitance of the third and fourth capacitors is operable to decrease; and

determining an acceleration of the accelerometer based at least in part on the detecting.

2. The method of claim 1, wherein detecting the change in acceleration includes measuring an electrical current across the at least four capacitors.

3. The method of claim 2, wherein measuring the electrical current includes:

measuring a change in capacitance of the at least four capacitors; and

measuring a change in voltage of the at least four capacitors.

4. The method of claim 1, wherein determining the acceleration includes determining the Z-axis acceleration.

5. The method of claim 1, wherein determining the acceleration includes using front-end readout circuitry connected to the at least four capacitors.

6. The method of claim 1, further comprising:

actuating a seismic energy source to produce seismic energy, wherein the acceleration of the accelerometer is based at least in part on the seismic energy.

7. The method of claim 1, further comprising:

towing another streamer behind the survey vessel in the body of water; and

actuating an acoustic transmitter on the another streamer to produce acoustic energy, wherein the acceleration of the accelerometer is based at least in part on the acoustic energy.

8. A sensor configured to receive seismic energy, the sensor comprising:

an accelerometer that includes:

a first substrate including a proof mass;

first and second spring layers respectively disposed on a first surface and a second, opposite surface of the first substrate;

first and second sets of at least two electrodes respectively disposed on the first and second spring layers;

a second substrate spaced from the first spring layer, wherein a third set of at least two electrodes are disposed on the second substrate at locations corresponding to those of the first set of electrodes; and

a third substrate spaced from the second spring layer, wherein a fourth set of at least two electrodes are disposed on the third substrate at locations corresponding to those of the second set of electrodes.

9. The sensor of claim 8, wherein the first and third sets of electrodes and the second and fourth sets of electrodes respectively form capacitors operable to detect variations in the proof mass.

10. The sensor of claim 8, wherein electrodes in the first, second, third, and fourth sets of electrodes are operable at least in part to apply a force to the proof mass.

11. The sensor of claim 8,

wherein the second substrate is spaced from the first spring layer by a vacuum-sealed cavity,

wherein the third substrate is spaced from the second spring layer by the vacuum-sealed cavity.

12. The sensor of claim 11,

wherein the vacuum-sealed cavity is bounded in part by bonding structures including metallic and silicon dioxide portions.

13. The sensor of claim 8, wherein each electrode in the first and second set of electrodes includes:

an oxide portion disposed on the first spring layer; and

a metal contact disposed on the oxide portion.

14. The sensor of claim 13, wherein the first substrate further includes first and second sets of piezoelectric structures respectively disposed on the first and second spring layers, wherein each piezoelectric structure in the first and second sets of piezoelectric structures includes:

a metallic portion disposed on the first spring layer;

a piezoelectric contact disposed on the metallic portion;

first and second oxide portions respectively disposed on opposite sides of the piezoelectric contact; and

a pair of electrodes disposed on the first and second oxide portions.

15. A sensor configured to receive seismic energy, the sensor comprising:

an accelerometer that includes:

a central substrate region;

a first bonded substrate opposing a first surface of the central substrate region;

a second bonded substrate opposing a second surface of the central substrate region;

a first pair of capacitors formed between the first bonded substrate and the central substrate region; and

a second pair of capacitors formed between the second bonded substrate and the central substrate region, wherein each of the first pair and second pair of capacitors includes a respective pair of electrodes, and wherein in response to an acceleration in a selected direction, a capacitance of the first pair of capacitors is operable to increase, and a capacitance of the second pair of capacitors is operable to decrease.

16. The sensor of claim 15, wherein the central substrate region includes:

a proof mass region bounded by a first spring structure, a second spring structure, a first protection structure, and a second protection structure.

17. The sensor of claim 16, further comprising:

a vacuum-sealed cavity bounded in part by the first and second bonded substrates, the first and second protection structures, a third protection structure, and a fourth protection structure.

18. The sensor of claim 17, wherein the first, second, third, and fourth protection structures are disposed laterally on either side of the proof mass region, and wherein the first and second bonded substrates are disposed vertically on either side of the central substrate region.

19. The sensor of claim 17, wherein the first, second, third, and fourth protection structure include silicon dioxide.

20. The sensor of claim 15, wherein the first bonded substrate includes a first getter layer, wherein the second bonded substrate includes a second getter layer.

21. A sensor configured to receive seismic energy, the sensor comprising:

an accelerometer that is a fully differential MEMS accelerometer configured to measure Z-axis acceleration of a proof mass, wherein the accelerometer includes:

a proof mass;

a first capacitor and a second capacitor on a first side of the proof mass; and

a third capacitor and a fourth capacitor on a second side of the proof mass;

wherein each of the four capacitors includes a respective pair of electrodes; and

wherein in response to the proof mass moving in a selected direction, a capacitance of the first and second capacitors is operable to increase, and a capacitance of the third and fourth capacitors is operable to decrease.

22. The sensor of claim 21, wherein the sensor includes a central substrate region including the proof mass, two anchor regions, and two portions of a vacuum-sealed cavity.