A single-axis accelerometer includes a housing defining a sleeve. An object/mass is disposed in the sleeve for sliding movement therein in a direction aligned with the sleeve’s longitudinal axis. A first piezoelectric strip, attached to a first side of the object and to the housing, is longitudinally aligned with the sleeve’s longitudinal axis. The first piezoelectric strip includes a first strip of a piezoelectric material with carbon nanotubes substantially aligned along a length thereof. A second piezoelectric strip, attached to a second side of the object and to the housing, is longitudinally aligned with the sleeve’s longitudinal axis. The second piezoelectric strip includes a second strip of the piezoelectric material with carbon nanotubes substantially aligned along a length thereof. A voltage sensor is electrically coupled to at least one of the first and second piezoelectric strips.
SINGLE-AXIS ACCELEROMETER

ORIGIN OF THE INVENTION

The invention described herein was made by employees of the United States Government and may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to accelerometers. More specifically, the invention is a single-axis accelerometer.

2. Description of the Related Art

Conventional accelerometers generally utilize a pendulum’s movement or a piezoelectric material to sense acceleration. Pendulum-based accelerometers are relatively large and expensive. Piezoelectric-based accelerometers are traditionally made from ceramic materials such as barium titanate (BaTiO₃) or lead titanate (PZT). However, these materials are inherently brittle, have a tendency to be noisy, have difficulty sensing low frequencies, and are subject to static charge build-up that affects polarization. Still further, piezoelectric materials used in “micro electro-mechanical system” (MEMS) accelerometers behave as a spring system that generates noise requiring compensation.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide an accelerometer.

Another object of the present invention is to provide a carbon nanotube-piezoelectric-based accelerometer that avoids the drawbacks generally associated therewith.

Other objects and advantages of the present invention will become more obvious hereinafter in the specification and drawings.

In accordance with the present invention, a single-axis accelerometer includes a housing defining a sleeve having a longitudinal axis. An object having a mass is disposed in the sleeve for sliding movement therein in a direction aligned with the sleeve’s longitudinal axis. A first piezoelectric strip is attached to a first side of the object and to the housing. The first piezoelectric strip is longitudinally aligned with the sleeve’s longitudinal axis. The first piezoelectric strip includes a first strip of a piezoelectric material with carbon nanotubes substantially aligned along a length of the first strip. A second piezoelectric strip is attached to a second side of the object and to the housing. The second side of the object opposes the first side. The second piezoelectric strip is longitudinally aligned with the sleeve’s longitudinal axis. The second piezoelectric strip includes a second strip of the piezoelectric material with carbon nanotubes substantially aligned along a length of the second strip. A voltage sensor is electrically coupled to at least one of the first piezoelectric strip and second piezoelectric strip.

BRIEF DESCRIPTION OF THE DRAWING(S)

Other objects, features and advantages of the present invention will become apparent upon reference to the following description of the preferred embodiments and to the drawings, wherein corresponding reference characters indicate corresponding parts throughout the several views of the drawings and wherein:
A variety of techniques can be used to fabricate piezoelectric strips 18 and 20. For example, piezoelectric matrix material 180 can be sprayed onto CNTs 182 as the CNTs were being drawn and then wound onto a spool. The drawing of CNTs 182 will cause their substantial alignment as the matrix material is sprayed thereon. To facilitate spraying, the piezoelectric matrix material can be mixed into a solvent such as polyvinylidene fluoride (PVDF) or polyvinylidene trifluoroethylene (PVDF-TrFE). To enhance the piezoelectric effect produced by piezoelectric strip 18, additives such as magnesium niobate-lead titanate (PMN-PT), lead zirconium titanate (PZT), and barium titanate (BaTiO₃) can be added to piezoelectric matrix 180.

Another accelerometer embodiment of the present invention is illustrated in FIG. 3 and is referenced generally by numeral 30. The elements of accelerometer 30 that are the same as accelerometer 10 are referenced with the same numerals and will not be described again herein. Accelerometer 30 is actively damped by including a voltage source 32 electrically coupled to piezoelectric strip 20. Voltage source 32 is coupled across the thickness of strip 20. In general, voltage source 32 applies a voltage to strip 20 to actively dampen oscillations in strip 20 when accelerometer 30 experiences acceleration along longitudinal axis 12A. Accordingly, accelerometer 30 is effectively a spring-damper system that can dampen oscillations that are inherent in piezoelectric materials in order to improve the response of accelerometer 30. Since piezoelectric strip 20 also includes CNTs therein, minimal voltage is needed to make piezoelectric strip 20 act as a damper. This will allow accelerometer 30 to be miniaturized and utilize low voltage levels typically available from conventional microcontrollers.

The advantages of the present invention are numerous. A simple single-axis accelerometer avoids the size constraints of pendulum-based accelerometers and avoids the drawbacks of conventional piezoelectric-based accelerometers. The piezoelectric strips are flexible and less noisy than ceramic materials, but are more responsive due to the inclusion of CNTs. The accelerometer can be actively damped with a low-level voltage to improve response.

Although the invention has been described relative to a specific embodiment thereof, there are numerous variations and modifications that will be readily apparent to those skilled in the art in light of the above teachings. It is therefore to be understood that, within the scope of the appended claims, the invention may be practiced other than as specifically described.

What is claimed as new and desired to be secured by Letters Patent of the United States is:

1. A single-axis accelerometer, comprising:
   a housing defining a sleeve having a longitudinal axis;
   an object having a mass disposed in said sleeve for sliding movement therein in a direction aligned with said longitudinal axis;
   a first piezoelectric strip attached to a first side of said object and attached to said housing, said first piezoelectric strip longitudinally aligned with said longitudinal axis, said first piezoelectric strip including a first strip of a piezoelectric material with carbon nanotubes substantially aligned along a length of said first strip;
   a second piezoelectric strip attached to a second side of said object and attached to said housing, said second side opposing said first side, said second piezoelectric strip longitudinally aligned with said longitudinal axis, said second piezoelectric strip including a second strip of said piezoelectric material with carbon nanotubes substantially aligned along a length of said second strip; and
   a voltage sensor electrically coupled to at least one of said first piezoelectric strip and said second piezoelectric strip.

2. A single-axis accelerometer as in claim 1, wherein said piezoelectric material is selected from the group consisting of polyvinylidene fluoride (PVDF) and polyvinylidene trifluoroethylene (PVDF-TrFE).

3. A single-axis accelerometer as in claim 1, further comprising additives mixed in said piezoelectric material, said additives being selected from the group consisting of magnesium niobate-lead titanate (PMN-PT), lead zirconium titanate (PZT), and barium titanate (BaTiO₃).

4. A single-axis accelerometer as in claim 2, further comprising additives mixed in said piezoelectric material, said additives being selected from the group consisting of magnesium niobate-lead titanate (PMN-PT), lead zirconium titanate (PZT), and barium titanate (BaTiO₃).

5. A single-axis accelerometer as in claim 1, further comprising a voltage source coupled to one of said first piezoelectric strip and said second piezoelectric strip.

6. A single-axis accelerometer, comprising:
   a housing defining a sleeve having a longitudinal axis;
   an object having a mass disposed in and constrained by said sleeve for sliding movement therein only in a direction aligned with said longitudinal axis;
   a first piezoelectric strip attached to a first side of said object and attached to said housing, said first piezoelectric strip longitudinally aligned with said longitudinal axis, said first piezoelectric strip including a first strip of a piezoelectric material with carbon nanotubes embedded in and substantially aligned along a length of said first strip;
   a second piezoelectric strip attached to a second side of said object and attached to said housing, said second side opposing said first side, said second piezoelectric strip longitudinally aligned with said longitudinal axis, said second piezoelectric strip including a second strip of said piezoelectric material with carbon nanotubes embedded in and substantially aligned along a length of said second strip; and
   a voltage sensor electrically coupled to one of said first piezoelectric strip and said second piezoelectric strip.

7. A single-axis accelerometer as in claim 6, wherein said piezoelectric material is selected from the group consisting of polyvinylidene fluoride (PVDF) and polyvinylidene trifluoroethylene (PVDF-TrFE).

8. A single-axis accelerometer as in claim 6, further comprising additives mixed in said piezoelectric material, said additives being selected from the group consisting of...
9. A single-axis accelerometer as in claim 7, further comprising additives mixed in said piezoelectric material, said additives being selected from the group consisting of magnesium niobate-lead titanate (PMN-PT), lead zirconium titanate (PZT), and barium titanate (BaTiO₃).

10. A single-axis accelerometer as in claim 6, further comprising a voltage source coupled to one of said first piezoelectric strip and said second piezoelectric strip.

11. A single-axis accelerometer, comprising:

   a housing defining a sleeve having a longitudinal axis;
   an object having a mass disposed in and constrained by said sleeve for sliding movement therein only in a direction aligned with said longitudinal axis, wherein air spaces are defined in said sleeve on opposing sides of said object;
   a first piezoelectric strip attached to a first of said opposing sides of said object and attached to said housing, said first piezoelectric strip disposed in one of said air spaces and longitudinally aligned with said longitudinal axis, said first piezoelectric strip including a first strip of a piezoelectric material with carbon nanotubes embedded in and substantially aligned along a length of said first strip, said carbon nanotubes occupying approximately 30-50 volume percent of said first piezoelectric strip;
   a second piezoelectric strip attached to a second of said opposing sides of said object and attached to said housing, said second piezoelectric strip disposed in another of said air spaces and longitudinally aligned with said longitudinal axis, said second piezoelectric strip including a second strip of said piezoelectric material with carbon nanotubes embedded in and substantially aligned along a length of said second strip, said carbon nanotubes occupying approximately 30-50 volume percent of said second piezoelectric strip; and
   a voltage sensor electrically coupled to one of said first piezoelectric strip and said second piezoelectric strip.

12. A single-axis accelerometer as in claim 11, wherein said piezoelectric material is selected from the group consisting of polyvinylidene fluoride (P(VDF)) and polyvinylidene trifluoroethylene (P(VDF-TrFE)).

13. A single-axis accelerometer as in claim 11, further comprising additives mixed in said piezoelectric material, said additives being selected from the group consisting of magnesium niobate-lead titanate (PMN-PT), lead zirconium titanate (PZT), and barium titanate (BaTiO₃).

14. A single-axis accelerometer as in claim 12, further comprising additives mixed in said piezoelectric material, said additives being selected from the group consisting of magnesium niobate-lead titanate (PMN-PT), lead zirconium titanate (PZT), and barium titanate (BaTiO₃).

15. A single-axis accelerometer as in claim 11, further comprising a voltage source coupled to another of said first piezoelectric strip and said second piezoelectric strip.

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