

- 2 -

detection device 5. Then, only both the edge surfaces of the longitudinal detection device 5 are securely supported by a casing 6 formed in a "U" shape as viewed from the lateral side.

5 The longitudinal piezoelectric ceramic sheets 3 and 4 are divided into central portions 3a and 4a and peripheral portions 3b and 4b by a pair of boundary lines L0 where stresses produced by the action of acceleration are changed. The central portion 3a and the peripheral portions 3b of the ceramic sheet 3 are respectively
10 polarized in the directions A and B inverted to each other along the thickness of the sheet 3, while the central portion 4a and the peripheral portions 4b of the sheet 4 are respectively polarized in the directions C and D inverted to each other along the thickness of the
15 sheet 4. The sheets 3 and 4 are then allowed to face each other in such a manner that the directions of polarization A and C at the respective central portions 3a and 4a are opposite, and that the directions of
20 polarization B and D at the respective peripheral portions 3b and 4b are opposite.

~~{Namely}~~ More specifically, in the piezoelectric ceramic sheets 3 and 4, the opposite directions of polarization A and C are oriented inwardly
25 to be close to each other at the central portions 3a and 4a, while the opposite directions of polarization B and D are oriented outwardly to be away from each other at the peripheral portions 3b and 4b. The signal extracting electrodes 1 disposed on the outer main surfaces of the
30 respective ceramic sheets 3 and 4 are electrically connected to external lead electrodes 7 and 8 formed on different edge surfaces of the casing 6, respectively.

SPEC#191608

This Sheet Has Been Replaced



- 3 -

For polarizing the ceramic sheets 3 and 4, electrodes used for polarization having sizes corresponding to the respective central portions 3a and 4a and the peripheral portions 3b and 4b have generally been formed, though they are not shown. Subsequent to this polarization process, the signal extracting electrodes 1 are, in general, laminated on these polarizing electrodes.

The reason for the use of the detection device 5 constructed as described above is given below. By the action of acceleration produced upon the acceleration sensor, the central portions 3a and 4a and the peripheral portions 3b and 4b of the ceramic sheets 3 and 4 are deformed due to an inertial force so that tensile stress or compressive stress is generated therein. This increases the amount of electrical charges in the above portions 3a, 4a, 3b and 4b due to a synergistic effect between the respective directions of polarization A through D and tensile stress or compressive stress, accordingly increasing the amount of charges in the overall detection device 5. Thus, detection sensitivity of the acceleration sensor can be improved.

In the above known type of acceleration sensor, the positions of the boundary lines L0 for dividing the longitudinal regions of the ceramic sheets 3 and 4 forming the detection device 5 into the central portions 3a and 4a and the peripheral portions 3b and 4b are determined to satisfy a required level of detection sensitivity of the acceleration sensor achieved by the increased electrical charges due to the generation of tensile stress or compressive stress in the central portions 3a and 3b and the peripheral portions 4a and 4b. More specifically, the positions of the boundary lines L0

SPRCV191608

This Sheet Has Been Replaced



- 4 -

are set by calculation according to one of the numerical analysis techniques, for example, the finite-element method.

It is, however, difficult to provide a required level of detection sensitivity for all the acceleration sensors because of a slight difference in the material of the ceramic sheets 3 and 4 between the individual lots, or even within the same lot. Also, different levels of detection sensitivity may be incurred due to working errors. Thus, the levels of detection sensitivity possessed by the individual acceleration sensors are disadvantageously varied. Namely, if the positions of the boundary lines L0 in the detection device 5 are merely determined so that the level of sensitivity can be matched to a target value, defective sensors beyond the tolerance of the target value are unavoidably manufactured, thereby incurring serious losses.

SUMMARY OF THE INVENTION

20 Accordingly, it is an object of the present
invention to provide an acceleration sensor, free from
the above-described problem, in which its detection
sensitivity can be maintained within the tolerance of a
predetermined target value, and also to provide a
25 manufacturing method for the acceleration sensor in which
its detection sensitivity can be positively kept within
the tolerance of a prescribed target value.

30 In order to achieve the above object, according to one form of the present invention, there is provided an acceleration sensor comprising a bimorph detection device longitudinally divided into a central portion and peripheral portions, the direction of polarization at

SPBCY191606

This Sheet Has Been Replaced



- 5 -

said central portion being inverted to the direction of polarization at said peripheral portions, wherein the ratio (Y/X) of the overall length (Y) of the central portion to the freely-deflectable length (X) of the bimorph detection device in the longitudinal direction ranges from 44% to 73%.

In the above type of acceleration sensor, the bimorph detection device may comprise a pair of piezoelectric ceramic sheets each formed in a rectangularly planar shape and longitudinally divided into the central portion and the peripheral portions, the direction of polarization at the central portion being inverted to the direction of polarization at the peripheral portions. The ceramic sheets may each have an electrode for extracting signals on the external main surface and an intermediate electrode on the internal main surface. Further, the piezoelectric ceramic sheets may be integrated by bonding the intermediate electrodes to each other in such a manner that the directions of polarization of the ceramic sheets may be opposite to each other.

According to another form of the present invention, there is provided a method for manufacturing ~~an~~ a production acceleration sensor which comprises a production bimorph detection device longitudinally divided into a central portion and peripheral portions, the direction of polarization at the central portion being inverted to the direction of polarization at the peripheral portions, the method comprising the steps of: producing a sample bimorph detection device after positioning boundary lines for longitudinally dividing the device into the central portion and the peripheral

SYNCH191600

This Sheet Has Been Replaced



- 6 -

portions; measuring the detection sensitivity of ~~{an}~~ a
sample acceleration sensor manufactured as a sample
product by integrating the sample bimorph detection
device into a sample casing; producing a production
5 bimorph detection device by correcting the positions of
the boundary lines toward the central portion or toward
the peripheral portions ~~{in consideration of the
measurements of}~~ based on the detection sensitivity of
the sample acceleration sensor; and manufacturing ~~{an}~~ a
10 production acceleration sensor by integrating the
production bimorph detection device into ~~{the}~~ a
production casing.

Other features and advantages of the present
invention will become apparent from the following
15 description of the invention which refers to the
accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a cutaway perspective view
illustrating the construction of an acceleration sensor
20 according to an embodiment of the present invention;

Fig. 2 illustrates the manufacturing process of
the acceleration sensor shown in Fig. 1; and

Fig. 3 is a cutaway perspective view
illustrating the construction of a known type of
25 acceleration sensor.

DESCRIPTION OF THE PREFERRED EMBODIMENT

An embodiment of the present invention will now
be described with reference to the drawings.

30 Referring to Figs. 1 and 2 illustrating an
acceleration sensor of this embodiment, there are shown a
detection device 10 and a pair of piezoelectric ceramic

SPICY191605

This Sheet Has Been Replaced



- 7 -

5 sheets 11 and 12. The overall construction of this sensor is basically similar to that of the conventional sensor shown in Fig. 3, and thus, the same elements as those illustrated in Fig. 3 are designated by like reference numerals.

10 A reference will be first made to Fig. 1. The acceleration sensor constructed in accordance with this embodiment of the present invention has a pair of rectangular planar piezoelectric ceramic sheets 11 and 12. An electrode 1 for extracting signals and an intermediate electrode 2 are formed on the main surfaces of each of the sheets 11 and 12. The intermediate electrodes 2 disposed on the internal main surfaces of the sheets 11 and 12 are bonded to face each other, thereby integrating the sheets 11 and 12 to form the detection device 10. Only both the edge surfaces of the longitudinal detection device 10 are securely held by a casing 6 formed in a "U" shape as viewed from the lateral side. The longitudinal regions of the ceramic sheets 11 and 12 are partitioned into central portions 11a and 12a and peripheral portions 11b and 12b by a pair of boundary lines L1 whose location is determined according to the following procedure. The longitudinal length of the detection device 10, except for both the lateral edges supported by the casing 6, i.e., the length in which the detection device 10 is freely deflectable, is determined as a freely-deflectable length X; while the overall length of the central portions 11a and 12a, is indicated by Y. The ratio Y/X of the overall length Y to the freely-deflectable length X is set to range from 44% to 73%.

More specifically, for example, when the ceramic sheets 11 and 12 each have an overall

SPK01191606

This Sheet Has Been Replaced



- 8 -

longitudinal length of 6.4 mm and a thickness of 0.12 mm,
and the longitudinal freely-deflectable length X of the
detection device 10 is 5.4 mm, the overall length Y of
the central portions 11a and 12a is set to range from 2.4
5 mm ($Y/X \approx 44.4\%$) to 3.9 mm ($Y/X \approx 72.2\%$). The above-
constructed acceleration sensors were tested by the
present inventors, and it has been proved that the levels
of the detection sensitivity of all of the acceleration
sensors can be contained within the tolerance of the
10 target value ranging from 1.95 to 2.25 mV/G.

Further, the central portion 11a and the
peripheral portions 11b of the ceramic sheet 11 are
polarized along the thickness of the sheet 11 in the
inverted directions of polarization A and B, while the
15 central portion 12a and the peripheral portions 12b of
the sheet 12 are polarized along the thickness of the
sheet 12 in the inverted directions of polarization C and
D. Then, the sheets 11 and 12 are integrated to each
other in such a manner that the directions of
20 polarization A and C at the respective central portions
11a and 12a are opposite and that the directions of
polarization B and D at the respective peripheral
portions 11b and 12b are opposite. ~~{Namely}~~ More
specifically, in the ceramic sheets 11 and 12, the
25 directions of polarization A and C are oriented inwardly
to be close to each other at the central portions 11a and
12a, while the directions of polarization B and D are
oriented outwardly to be away from each other at the
peripheral portions 11b and 12b. The signal extracting
30 electrodes 1 disposed on the external main surfaces of
the respective ceramic sheets 11 and 12 are electrically
connected to external lead electrodes 7 and 8,

SPICE191608

This Sheet Has Been Replaced



- 9 -

respectively, formed on the different lateral surfaces of the casing 6. It should be noted that the directions A through D in which the central and peripheral portions 11a, 11b, 12a and 12b of the ceramic sheets 11 and 12 are
5 polarized may be oriented reverse to those designated above. Such an alternative construction of the acceleration sensor is naturally applicable to the present invention.

The acceleration sensor constructed as
10 illustrated in Fig. 1 is manufactured according to the below-described method of the present invention. Prior to production of acceleration sensors put to practical use, sample products will be initially produced.

More specifically, a pair of nonpolarized
15 piezoelectric ceramic sheets, i.e., the ones equivalent to the ceramic sheets 3 and 4 used in the example of conventional acceleration sensors discussed above, ~~have been~~ are sampled from the individual product lots, or within the same lot. The boundary lines L0 serving to
20 divide the longitudinal regions of the sheets 3 and 4 into three portions are then positioned and set by calculation, for example, according to the finite-element method. Mask patterns having sizes corresponding to the central portions 3a and 4a and the peripheral portions 3b
25 and 4b of the ceramic sheets 3 and 4, which are partitioned by the pair of boundary lines L0, as shown in Fig. 2, are provided. By use of these mask patterns, electrodes used for polarization 13 are formed on the external main surfaces of the sheets 3 and 4.
30 Subsequently, the intermediate electrodes 2 are disposed on the internal main surfaces of the respective sheets 3 and 4. With this arrangement, high voltages are applied

EXPCF191602

This Sheet Has Been Replaced



- 10 -

to the ceramic sheets 3 and 4 through the above electrodes in such a manner that the directions of polarization at the central portion 3a and the peripheral portion 3b of the sheet 3 are inverted to each other and
5 that the directions of polarization at the central portion 4a and the peripheral portion of the sheet 4 are inverted to each other. It should be noted that only the ceramic sheet 3 is shown in Fig. 2.

Further, the signal extracting electrodes 1 are
10 laminated on the respective polarizing electrodes 13 formed on the polarized ceramic sheets 3 and 4, and then, the intermediate electrodes 2 disposed on the internal main surfaces of the sheets 3 and 4 are integrated to face each other. The detection device 5 can thus be
15 produced. Subsequently, only both the edge surfaces of the longitudinal device 5 are securely held by the casing 6, and the signal extracting electrodes 1 are electrically connected to the external lead electrodes 7 and 8, respectively, disposed on different lateral edge
20 surfaces of the casing 6. In this manner, a plurality of acceleration sensors having a built-in detection device 5 in the casing 6, i.e., acceleration sensors constructed in a manner similar to the sensor of the example of conventional sensors shown in Fig. 3, can be manufactured
25 as sample products.

By measuring the levels of detection sensitivity possessed by the individual sample acceleration sensors, variations in the detection sensitivity of the samples can be detected, thereby
30 making it possible to identify the presence of differences in the materials of the piezoelectric ceramic sheets of the individual lots, or within the same lot,

SPENCER151608

This Sheet Has Been Replaced



- 11 -

and also to identify the presence of the working errors of the sheets. In light of the measurements of the detection sensitivity of the above sample products, the detection device 10 will be newly produced. More particularly, the locations of the boundary lines L1 for partitioning the longitudinal regions of the ceramic sheets 11 and 12 into the central portions 11a and 12a and the peripheral portions 11b and 12b are corrected to be toward the central portions 11a and 12a or toward the peripheral portions 11b and 12b.

More specifically, if the levels of detection sensitivity of the sample products are somewhat higher, the boundary lines L1 are corrected to be positioned toward the central portions 11a and 12a, thereby adjusting the detection sensitivity of the acceleration sensor to a lower level. In contrast, if the levels of detection sensitivity of the sample products are somewhat lower, the boundary lines L1 are corrected to be located toward the peripheral portions 11b and 12b, thereby regulating the detection sensitivity of the sensor to a higher level.

Afterwards, mask patterns having sizes corresponding to the central portions 11a and 12a and the peripheral portions 11b and 12b of the ceramic sheets 11 and 12 extracted from the individual lots, or within the same lot, and provided with the pair of corrected boundary lines L1, as shown in Fig. 2, have been provided. By utilizing the mask patterns, the polarizing electrodes 13 are disposed on the external main surfaces of the ceramic sheets 11 and 12, and the intermediate electrodes 2 are formed on the internal main surfaces of the sheets 11 and 12. High voltages are then applied to the sheets

SP2C7191600

This Sheet Has Been Replaced



- 13 -

In a manner similar to the example of conventional acceleration sensors, upon providing acceleration to the sensor of this embodiment, the central portions 11a and 12a and the peripheral portions 11b and 12b of the piezoelectric ceramic sheets 11 and 12 forming the detection device 10 are deformed due to an inertial force, so that tensile stress or compressive stress is produced in these portions 11a, 12a, 11b and 12b. As a consequence, the amount of electrical charges are increased in the ceramic sheets 11 and 12 due to a synergistic effect between the directions of polarization A through D at the individual portions and tensile or compressive stress generated therein.

As will be clearly understood from the foregoing description, the present invention offers the following advantages. The detection sensitivity of the acceleration sensors according to the present invention can be maintained within the tolerance of a prescribed target value without being adversely influenced by differences in the materials of piezoelectric ceramic sheets selected from the individual product lots, or within the same lot, or without being affected by working errors of the sheets. This can obviate defective products beyond the tolerance of a target value, which would otherwise incur losses. Additionally, according to the manufacturing method of the present invention, the detection sensitivity of the acceleration sensors can be reliably maintained within the tolerance of a target value.

Although the present invention has been described in relation to particular embodiments thereof, many other variations and modifications and other uses

57007191400

This Sheet Has Been Replaced



- 14 -

will become apparent to those skilled in the art. It is preferred, therefore, that the present invention be limited not by the specific disclosure herein, but only by the appended claims.

SPECV191608

This Sheet Has Been Replaced





- 15 -

WHAT IS CLAIMED IS:

1. An acceleration sensor comprising a bimorph detection device having a freely-deflectable length (X) in a longitudinal direction and longitudinally divided into a central portion having a length (Y) in the longitudinal direction and peripheral portions, the direction of polarization at said central portion being inverted to the direction of polarization at said peripheral portions,
- 5
- wherein the ratio (Y/X) of the overall length (Y) of said central portion to the freely-deflectable length (X) of said bimorph detection device [in the longitudinal direction] ranges from 44% to 73%.
- 10

2. An acceleration sensor according to claim 1, wherein said bimorph detection device comprises a pair of piezoelectric ceramic sheets each formed in a rectangularly planar shape and longitudinally divided
- 5
- into the central portion and the peripheral portions, the direction of polarization at said central portion being inverted to the direction of polarization at said peripheral portions, said ceramic sheets each having an electrode for extracting signals on the external main surface and an intermediate electrode on the internal main surface, and wherein said piezoelectric ceramic sheets are integrated by bonding said intermediate electrodes to each other in such a manner that the directions of polarization of said ceramic sheets are
- 10
- opposite to each other.
- 15

3. An acceleration sensor according to claim 2.

5280191608

This Sheet Has Been Replaced





- 16 -

wherein each ceramic sheet includes respective polarization electrodes for polarizing the central portion and the peripheral portions.

~~{3}~~ 4. A method for manufacturing ~~{an}~~ a production acceleration sensor which ~~{comprises-~~
~~a }~~includes a production bimorph detection device
longitudinally divided into a central portion and
5 peripheral portions, the direction of polarization at
said central portion being inverted to the direction of
polarization at said peripheral portions, said method
comprising the steps of:

producing a sample bimorph detection device
10 after positioning boundary lines for longitudinally
dividing said device into the central portion and the
peripheral portions;

measuring the detection sensitivity of ~~{an}~~ a
sample acceleration sensor manufactured as a sample
15 product by integrating said bimorph detection device into
a sample casing;

producing ~~{a}~~ said production bimorph detection
device by correcting the positions of the boundary lines
toward the central portion or toward the peripheral
20 portions ~~{in consideration of the}~~ based measurements of
the detection sensitivity of said sample acceleration
sensor; and

manufacturing ~~{an}~~ said production acceleration
sensor by integrating said production bimorph detection
25 device into ~~{the casing-}~~ a production casing.

5. A method according to claim 4, wherein the
production bimorph device has a freely-deflectable length

SPDCN191600

This Sheet Has Been Replaced





- 17 -

5 (X) in the longitudinal direction and the central portion
has a length (Y) in the longitudinal direction and
wherein said boundary lines are corrected so that the
ratio (Y/X) of the overall length (X) of said central
portion to the freely-deflectable length (X) ranges from
44% to 73%.

5 6. A method according to claim 5, wherein each
of said sample bimorph detection device and said
production bimorph detection device comprises a pair of
piezoelectric ceramic sheets each formed in a
rectangularly planar shape and longitudinally divided
into the central portion and the peripheral portions, the
direction of polarization at said central portion being
inverted to the direction of polarization at said
peripheral portions, said ceramic sheets each having an
10 electrode for extracting signals on the external main
surface and an intermediate electrode on the internal
main surface, and wherein said piezoelectric ceramic
sheets are integrated by bonding said intermediate
electrodes to each other in such a manner that the
15 directions of polarization of said ceramic sheets are
opposite to each other.

7. A method according to claim 6, wherein each
ceramic sheet includes respective polarization electrodes
for polarizing the central portion and the peripheral
portions.

SPECN191608

This Sheet Has Been Replaced

