

METHOD OF MANUFACTURING AN ACCELEROMETER**FIELD OF INVENTION**

The invention relates to microelectromechanical devices and in particular to capacitive
5 microelectromechanical accelerometers.

BACKGROUND

Microelectromechanical accelerometers are currently being manufactured for a number of
10 applications including vehicle airbag and inertial navigation and guidance systems. For
applications such as vehicle airbags the accelerometers need to be both accurate and
inexpensive.

Microelectromechanical accelerometers are formed on a substrate using fabrication process
15 steps similar or identical to those used in integrated circuit fabrication. Microelectromechanical devices combine electrical and mechanical functionality into one
device. The fabrication of microelectromechanical devices is generally based on the
making and processing of alternate layer of polycrystalline silicon (polysilicon) and a
sacrificial material such as silicon dioxide (SiO_2) or a silicate glass. The polysilicon layers
20 are built up and patterned layer by layer to form the structure of the device. Once the
structure is completed the sacrificial material is removed by etching to release the
polysilicon members of the microelectromechanical device for operation. The removal of
sacrificial material in some microelectromechanical accelerometers includes using an
isotropic release etch to release beams of the accelerometer from the bottom surface of the
25 accelerometer. This release etch has the disadvantage of etching away part of the beams
and reducing the proof mass and effectiveness of the accelerometer.

SUMMARY OF INVENTION

30 In broad terms in one aspect the invention comprises a method for fabricating an
accelerometer including the steps of, etching at least one cavity into the top side of a
substrate, bonding a layer of material onto the top side of the substrate, depositing

metalisation onto the layer of material to be used for electrical connections and etching the layer of material to form at least two independent sets of beams over each cavity.

5 Preferably the substrate is an insulating material. Ideally the substrate is formed from glass or another equivalent material.

Preferably each set of beams is anchored to the substrate.

10 Preferably one set of beams includes means to allow the beams to move with side to side motion from one end of the beams. Ideally the means to allow the beams to move is a spring or tether means.

15 Preferably the method of fabricating the accelerometer further includes the step of masking the substrate before the step of etching the substrate.

Preferably the method of fabricating the accelerometer further includes the step of patterning the mask using lithography processes.

20 Preferably the layer of suitable material is a silicon material.

Preferably the layer of suitable material is thinned as required.

25 Preferably the method of fabricating the accelerometer further includes the step of masking the layer of suitable material before the step of etching the sets of beams.

Preferably the method of fabricating the accelerometer further includes the step of patterning the masking layer to the pattern of the beams prior to the step of etching the sets of beams.

30 Preferably the method of fabricating the accelerometer further includes the step of performing an etchback to remove the unwanted masking layer after the sets of beams have been etched.

In broad terms in a further aspect the invention comprises an accelerometer including; a bottom substrate layer, at least one cavity in the bottom substrate layer, an upper layer, at least two sets of beams formed in the upper layer and suspended over the cavity, at least
5 one point suitable for electrical connection to each set of beams, wherein the cavity is formed before the suspended beams are formed.

BRIEF DESCRIPTION OF DRAWINGS

10 A preferred form system and method of the invention will be further described with reference to the accompanying figures by way of example only and without intending to be limiting, wherein;

Figure 1A shows a glass substrate with a masking layer,
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Figure 1B shows a substrate with an insulating layer and a masking layer,

Figure 2 shows the substrate with the masking layer patterned,

20 Figure 3 shows the substrate with cavities etched into the substrate,

Figure 4 shows the top layer bonded to the substrate,

Figure 5 shows the top layer thinned to the required thickness,
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Figure 6 shows the deposition of metalisation on the top layer,

Figure 7 shows the metalisation patterned to form electrical connections,

30 Figure 8 shows a masking layer over the top layer and metalisation patterned to the accelerometer sensor pattern,

Figure 9 shows the results of a trench etch producing the accelerometer sensor pattern,

Figure 10 shows the results of an etchback which has removed the masking layer, and

5 Figure 11 is a top view of an accelerometer formed using the method of the invention.

DETAILED DESCRIPTION OF PREFERRED FORMS

Figure 1A shows a substrate 1 of electrically insulating material. The substrate is covered
10 by masking layer 4 on its top surface. Substrate 1 may be formed from any suitable electrically insulating material such as glass, Pyrex or other materials with similar properties.

Figure 1B shows an alternative wafer arrangement where the substrate 2 is formed of
15 electrically conducting or semiconducting material such as silicon. In this arrangement substrate 2 has an electrically insulating layer 3 deposited on its top surface. Suitable materials for the insulating layer include oxide, nitride, PSG, glass frit, etc.

In both the arrangements of Figures 1A and 1B the top surface of the substrate 1 or the
20 insulating layer 3 is deposited with a masking layer 4. The masking layer is patterned with patterns for cavities to be formed in the substrate 1 (of the wafer of Figure 1A) or insulating layer 3 and substrate 2 (of the wafer of Figure 1B). The masking layer may also be patterned with marks for alignment purposes useful for later stage of the process. The masking layer may be formed from chrome or any other suitable material, for example
25 polysilicon. Figure 2 shows the masking layer once it has been patterned. Patterning of the masking layer may be using lithography processes as are well known to those skilled in the art and commonly used in the wafer fabrication industry.

Figure 3 shows cavities 5 etched into the substrate 1. Etching may be performed using any
30 suitable process such as wet chemical etching. After the cavities have been etched the remaining masking layer is removed.

Following this a top layer of semiconducting material 6 such as silicon is bonded to the substrate 1 as shown in Figure 4. Any suitable bonding technique may be used to bond the two layers together. For example a suitable technique may be anodic, eutectic or thermocompression bonding. Alternatively any other suitable technique may be used. If the top layer 6 is thicker than the thickness required for the sensor it is thinned to the required thickness. Techniques for thinning the top layer include wet chemical etching, backgrinding, lapping, chemical-mechanical polishing or a combination of these and other techniques.

Figure 5 shows the top layer 6 and substrate 1 bonded together with the top layer at the required thickness. The thickness of the top layer determines the thickness of the beams of the sensor. The capacitance of the sensor formed by the process is also related to the thickness of the beams. The sensitivity of the sensor to acceleration forces is also related to the thickness of the beams. The thicker the beams the bigger the capacitive charge for a given displacement of the beams. Another effect of thicker beams is a larger seismic or proof mass of the sensor. This also increases the sensitivity of the sensor to low g-forces.

Following the step of bonding the substrate 1 and the top layer 6 and the step of thinning the top layer (if necessary), metallization 7 is deposited onto the top of top layer 6. Metallization is used to form electrical connections to further electronics to be connected to the sensor. Figure 7 shows the patterning of metallization 7 to form the electrical connections.

The next step in the process is to deposit a masking layer 8 over the metallization 7 and the top layer 6. Again the masking layer 8 is patterned using a suitable process such as a lithography process. As can be seen in Figure 8 the masking layer has been patterned to form the sensor structure of the accelerometer. In this case the sensor structure of the accelerometer includes two comb like structure on each side of the cavity and a central beam with a comb like structure on each side. Each of the comb like structures extending from the central beam intermeshes with one or the other comb like structures (shown in more detail in Figure 11). However other suitable structures may be patterned onto the mask.

Following the patterning of the mask, the wafer is then etched as shown in Figure 9 to produce the structure of the sensor suspended over cavities 5 in substrate 1. This etch step may be performed by anisotropic etch. The step of forming cavities 5 in substrate 1 before bonding top layer 6 to the substrate removes the need to etch underneath the beams of the sensor to release them from the substrate by isotropic etching. This avoids the problems associated with isotropic etching including that isotropic etching consumes much of the thickness of the beams thereby reducing the sensitivity and capacitance of the sensor.

The final step in the process is performing an etch back to remove the unwanted masking layer 9 from the top of the sensor as shown in Figure 10. A further optional step is to provide a passivation layer over the metallization. The sensor is now functional and can be packaged on a wafer level to enable dicing the wafers into individual dies.

Figure 11 is a top view of a sensor formed using the method of the invention. As can be seen in Figure 11 the sensor structure is suspended over cavity 5. The sensor structure comprises four sets of fixed capacitive plates anchored to substrate 1 at anchor blocks 10. Each set of capacitive plates includes a set of beams attached at one end to a wider beam in a comb arrangement. The wider beam is then attached to the anchor block. A second set of capacitive plates is shown at 15. This set of capacitive plates has a central wider beam with smaller beams extending at right angles from both sides of the wider beam. The wider beam of this set of capacitive plates is tethered to anchors 12 by spring means 13. The spring means 13 allows capacitive plates 15 to move in the directions indicated by arrow 16. Any suitable means that allows movement of the capacitive plates in one direction may be used.

Each anchor block 10 or 12 includes an area 7 of metallization used for electrical contacts. The electrical contacts may also be provided at other area of the wafer connected to the anchor blocks 10 or 12. Although the anchor blocks all rest on the same substrate, the insulating properties of the bottom wafer keep the anchor blocks electrically insulated from one another. Cavity 5 under the structure, in the bottom wafer, allows the structure to be suspended and freely react to acceleration forces parallel to the wafer surface. This allows

a capacitance change caused by a force displacing the moving plates relative to the fixed plates to be sensed.

The foregoing describes the invention including preferred forms thereof. Alterations and
5 modifications as will be obvious to those skilled in the art are intended to be incorporated within the scope hereof as defined in the accompanying claims.



CLAIMS

1. A method of fabricating an accelerometer including the steps of:
etching at least one cavity into the top side of a substrate,
- 5 bonding a top layer of material onto the top side of the substrate,
depositing metallization onto the layer of material, and
etching the top layer of material to form a sensor structure suspended over each cavity.
2. A method of fabricating an accelerometer as claimed in claim 1 wherein the
10 substrate is an insulating material.
3. A method of fabricating an accelerometer as claimed in claims 1 wherein the
substrate is covered with a layer of insulating material.
- 15 4. A method of fabricating an accelerometer as claimed in any one of the preceding
claims further including the step of masking the substrate before each etching step.
5. A method of fabricating an accelerometer as claimed in claim 4 further including
the step of patterning the mask.
- 20 6. A method of fabricating an accelerometer as claimed in any one of claims 4 or 5
further including the step of patterning the masking layer to a pattern of beams before
etching the top layer of material to form the sensor structure.
- 25 7. A method of fabricating an accelerometer as claimed in any one of claims 4 to 6
further including the step of performing an etch back after each etching step to remove
unwanted masking layer.
8. An accelerometer including;
30 a bottom substrate layer,
a top layer bonded to the bottom layer,



- at least one cavity in the bottom substrate layer formed before the top layer is bonded to the bottom layer,
- a capacitive sensor structure formed in the top layer and suspended over the cavity, and at least one point suitable for electrical connection in contact with each part of the capacitive sensor structure.
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9. An accelerometer as claimed in claim 8 wherein the top layer is formed of a silicon material.
- 10 10. An accelerometer as claimed in claim 8 or claim 9 wherein the bottom layer is formed of insulating material.
11. An accelerometer as claimed in claim 8 or 9 wherein the bottom layer is covered with a layer of insulating material.