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G1N NAGB N1D13 N3S2 N7A1 N7B1 N7C
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EP 0319871 A1 WO 89/05963 A1 US 4867842 A
US 4501144 A

(58) Field of search
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INT CL[5] G01F 1/68

(54) Sensor for measuring fluid flow rate

(57) A sensor for measuring the velocity or flow rate of a flowing medium, in particular a gas, and which is exposed to the flowing medium, has a silicon base 1 to which there is applied a sequence of thin films in which a membrane 20 is formed. Between the membrane and the silicon base there is a cavity 15. The membrane has a resistor arrangement comprising at least one heating resistor 21 and at least one temperature-dependent sensor resistor 22 formed e.g. as doped polysilicon film elements. As shown the membrane consists of a polysilicon film 10, a silicon nitride insulating film 11, and an overall passivating film 12. Various forms and methods of manufacture are described. Since the device is also pressure sensitive, a "dummy" device which is not sensitive to temperature may be included in the sensor and used to compensate for pressure variations.

FIG. 1e

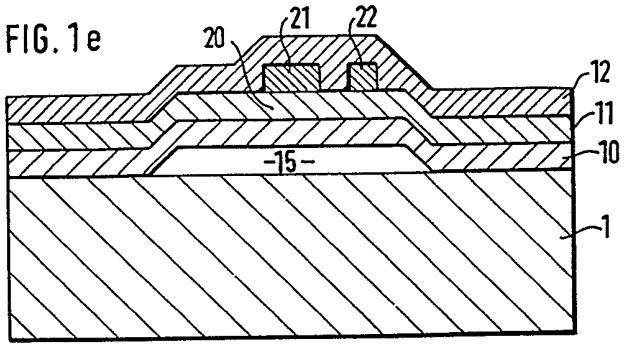

FIG. 2

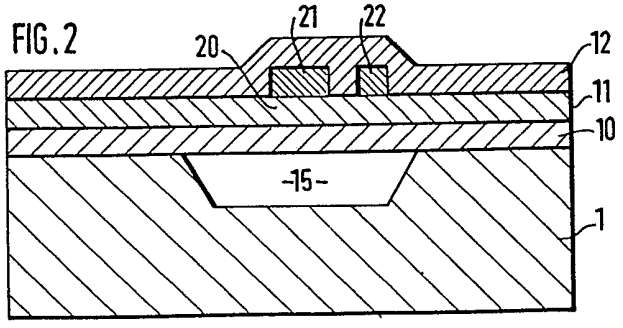

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FIG. 1a

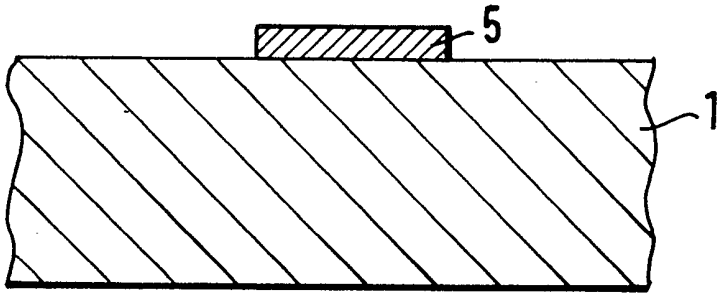


FIG. 1b

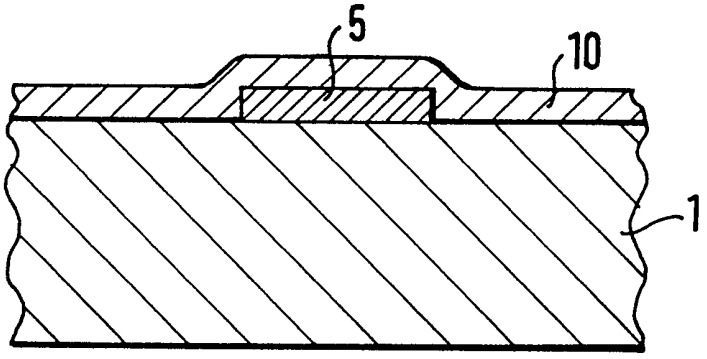


FIG. 1c

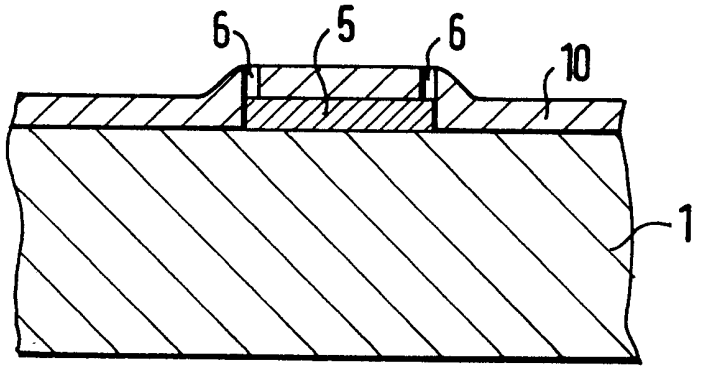


FIG. 1d

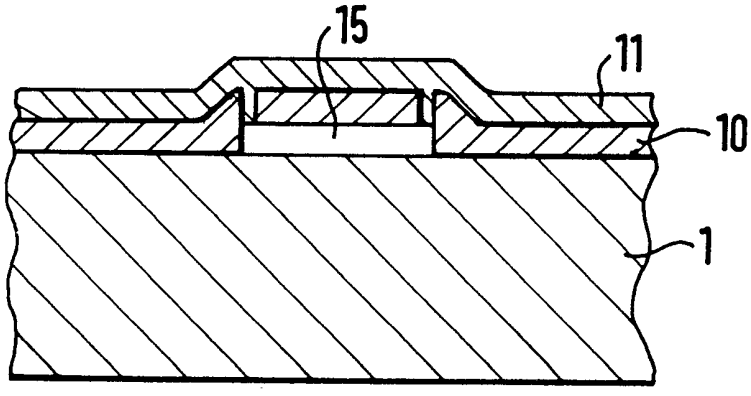


FIG. 1e

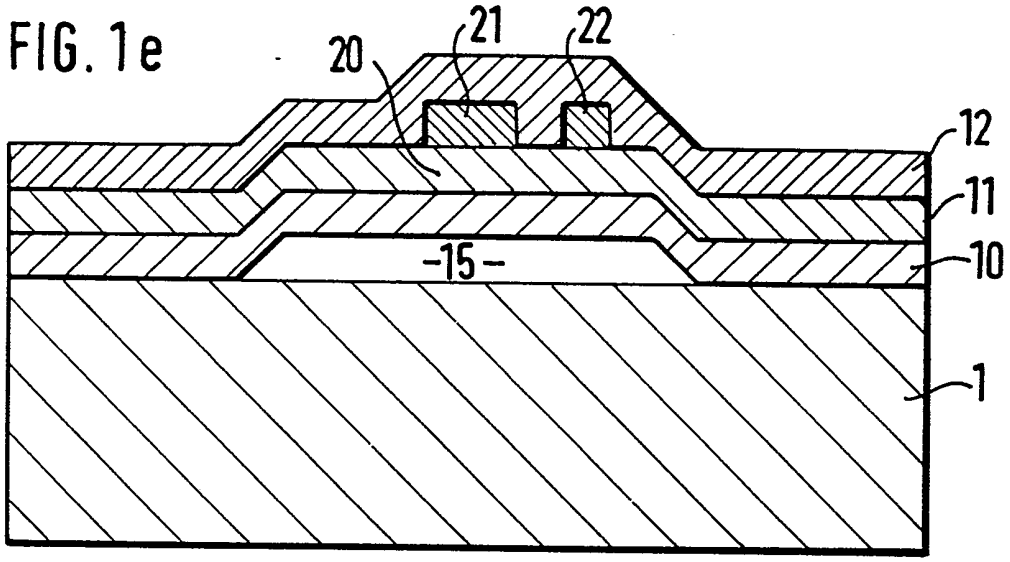


FIG. 2

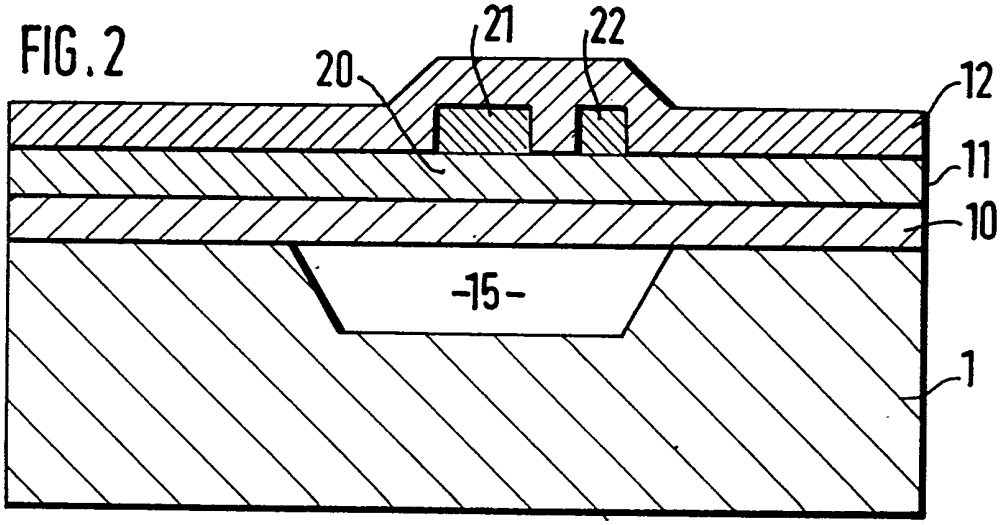


FIG. 3c

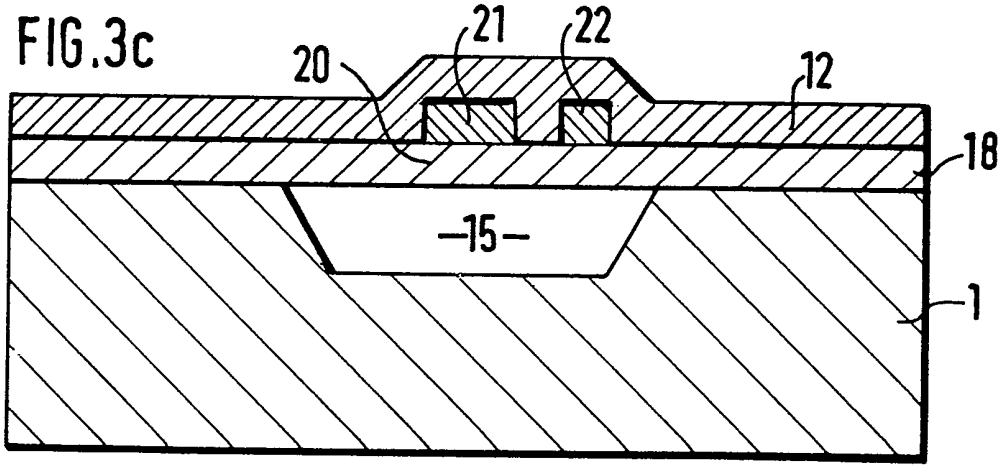


FIG. 3a

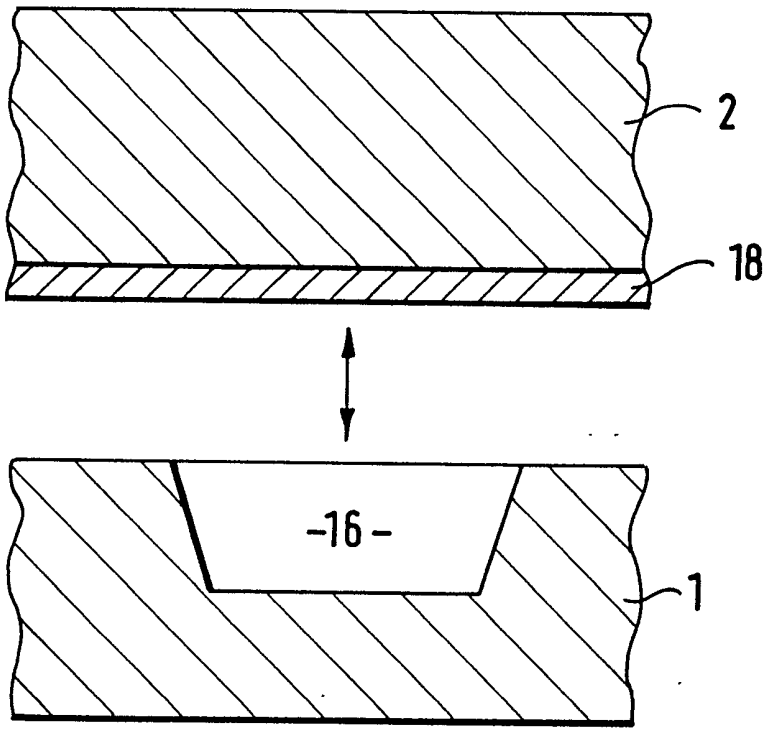


FIG. 3b

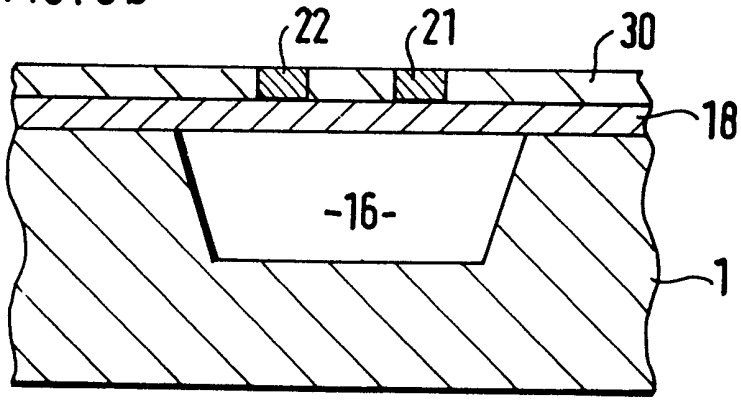


FIG. 4a

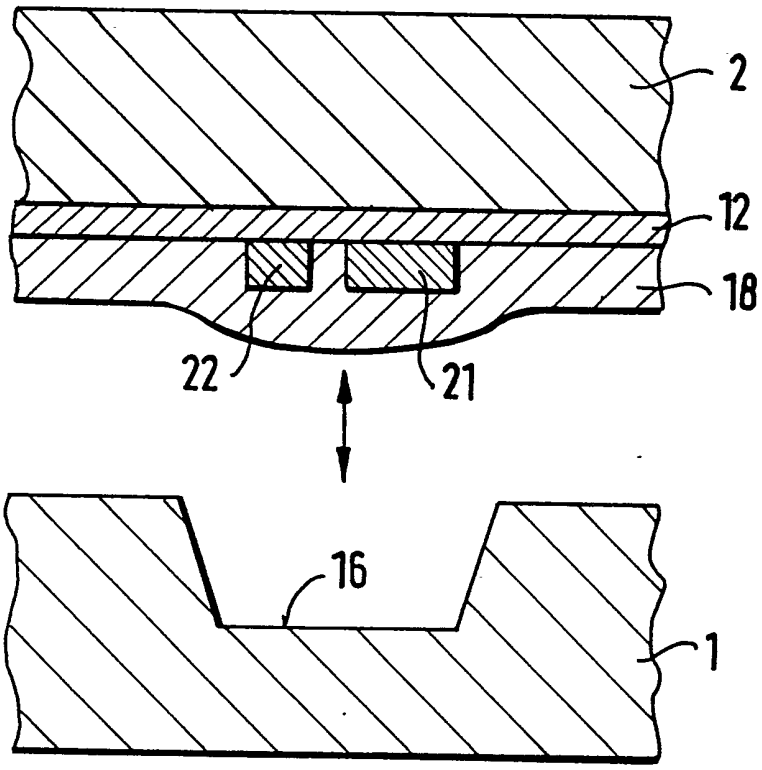


FIG. 4b

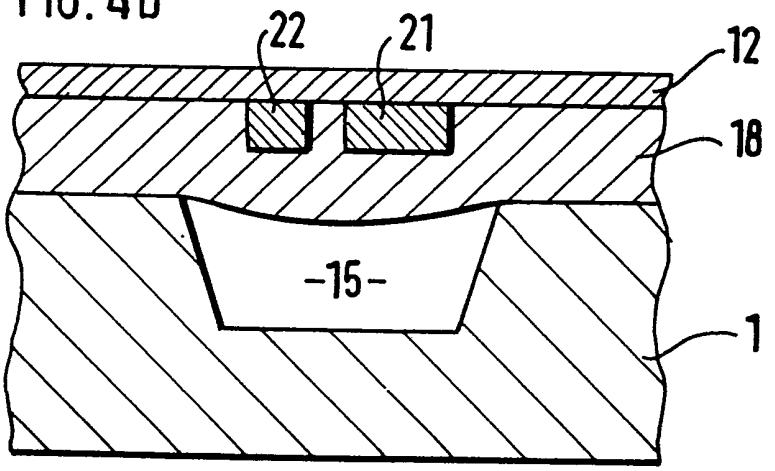
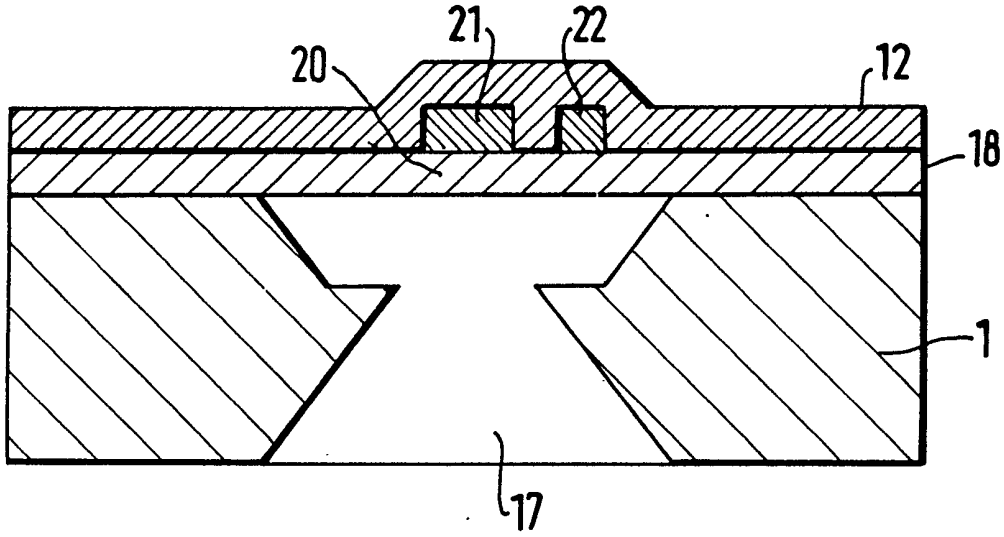


FIG. 5



Sensor

Prior art

The invention is based on a sensor for measuring the velocity or flow rate of a flowing medium according to the generic type of the main claim.

PCT application WO 90/02317 describes a device for measuring a flowing quantity of air having a sensor element which is exposed to the flowing air and constructed in thick-film technology and which has a resistor arrangement comprising a film-type heating resistor and a temperature-dependent sensor film resistor, the sensor film resistor being a component of a bridge circuit. The resistor arrangement is accommodated in a bubble which is composed of ceramic material, in particular of glass ceramic, and which is formed into a dome on an insulating substrate. The thin membrane forming the bubble and the cavity between the membrane and the substrate ensure a thermal decoupling of the film resistors from the substrate.

In "Fine Grained Polysilicon and its Application to Planar Pressure Transducers", H. Guckel et al., Transducers '87, page 277 - 282, the production of a micromechanical pressure sensor, in particular the production of a "pillbox" membrane of polysilicon in thin-film technology is described.

In "Single-cryistal Silicon Pressure Sensors with 500 x Overpressure Protection" [sic], Lee Christel et al, Sensors and Actuators, A21 - A23 (1990), 84-88, a process is presented for producing a pressure sensor which has a membrane and in which a recess is etched in a first

silicon wafer. In a further process step, a second wafer, which is made thinner in a third process step until it has the desired thickness of the sensor membrane, is bonded against the structured surface of the first wafer.

Advantages of the invention

The sensor according to the invention for measuring the velocity or the flow rate of a flowing medium having the characterising features of the main claim has the advantage that it can be produced with very small overall size. As a result, measurements can also be carried out in very thin tubes. In addition, the small overall size of the sensor makes possible multiple arrangements, so that the measurement uncertainty can be reduced by redundancy and the reliability can be increased. For this purpose, for example, the measurement signals of a plurality of devices can be averaged. Multiple arrangements of sensor elements can also advantageously be used to determine the movement profile of a flowing medium. The very small overall size of the sensor which is exposed to the flowing medium also has a very advantageous effect since the sensor affects the flow of the medium only insignificantly and the medium is virtually not swirled. The micromechanical implementation of the sensor according to the invention is also moderate in price since silicon is used as base material and many devices can be produced on one wafer. The production of the membrane by micromechanical surface technology is particularly inexpensive and makes possible a substantially stress-free structure of the sensor element. In addition, the integration of the evaluation electronics on the sensor itself is possible. It is particularly advantageous that the membrane can be produced very thinly in thin-film technology, typically 1 to 2 μm thick, so that the resistor arrangement composed of sensor resistor and heating resistor produced on the membrane can be thermally decoupled very well from the silicon base. This effect is further promoted by the use

of materials with low thermal conductivity, such as polysilicon, silicon nitride, silicon oxynitride and silicon oxide as membrane.

The measures listed in the subordinate claims make possible advantageous further developments of the sensor provided in the main claim. It is particularly advantageous if the spacing between membrane and silicon base is as large as possible. This can be achieved in that a silicon membrane is formed into a dome on the silicon base over auxiliary films which are later removed again, or, alternatively, by further additionally structuring the silicon base in its depth. A further advantageous measure for avoiding interfering effects, in particular as a result of the action of pressure on the sensor, is to etch the silicon base completely through, so that there is a pressure equalisation on both sides of the membrane. Another possibility for avoiding a measurement signal distortion due to pressure effects is to arrange a further membrane on the sensor element which is equipped with a temperature-independent sensor resistor exclusively for measuring pressure.

In Claims 13 to 17, advantageous processes are proposed for producing a sensor according to the invention. The sensor membrane can advantageously be produced by applying polysilicon films to structured silicon oxide auxiliary films and then removing the auxiliary films. An electrically insulating film to which the resistor arrangement is applied is then deposited on the polysilicon membrane. It is essential that this film structure is as stress-free as possible. The structured silicon oxide auxiliary films can advantageously be produced either by thermal oxidation of the masked surface of the silicon base or, alternatively, by depositing silicon oxide from a silane/oxygen atmosphere and then structuring the silicon oxide film. A further advantageous process for producing the sensor element is to etch a recess into the surface of a first silicon base and to deposit, on the surface of a second silicon base, a silicon oxide film,

against which the first silicon base with its structured surface is bonded. In a subsequent process step, the entire second silicon base is then etched away except for a small residual thickness which corresponds to the resistor thickness, so that the silicon oxide film forms a film of the sensor membrane. The resistor arrangement is then formed from the thin silicon film. An insulating protective film is furthermore finally deposited over the membrane with the resistor arrangement. In this process it is also possible to first introduce a recess into the surface of the second silicon base, deposit a first electrically insulating film over this structured surface of the second silicon base and apply the resistor arrangement, for example in the form of polysilicon films to said film in the region of the recess and finally to deposit a silicon oxide film thereover. After bonding the first silicon base with the structured surface against the second silicon base via the silicon oxide film, the entire second silicon base is again etched away, the silicon oxide film, the resistor arrangement and the insulating film serving as protective film forming the membrane.

Drawing

Exemplary embodiments of the invention are shown in the drawing and explained in greater detail in the description below.

Figures 1a to 1e show various process steps in the construction of a sensor element according to the invention, Figure 2 shows a section through a sensor element, Figures 3a to 3c show process steps for constructing a sensor element according to the invention by a second process, Figures 4a and 4b show different process steps corresponding to a third process and Figure 5 shows a section through a pressure-equalised sensor element.

Description of the exemplary embodiments

In Figure 1a, 1 denotes a silicon base to which a structured silicon oxide film 5 has been applied. The structured silicon oxide film 5 can be produced either by suitable masking of the surface of the silicon base 1 and subsequent thermal oxidation of the points of the surface of the silicon base 1 not covered by the masking or by an oxidation of the entire surface and subsequent photolithographic structuring of the oxide. In the case of thermal oxidation, the silicon oxide film 5 is produced from the silicon of the silicon base 1 and atmospheric oxygen. Said silicon oxide film partially extends into the surface of the silicon base 1. A further possibility for producing a structured silicon oxide film is to deposit a silicon oxide film on the surface of the silicon base 1 from a silane/oxygen atmosphere and then to structure it in a photomasking process.

Figure 1b shows the silicon base 1 with the structured silicon oxide film 5 which serves as auxiliary film and over which a polysilicon film 10 has been deposited. Etch channels 6 are introduced into the polysilicon film 10 in the region of the auxiliary film 5, and this is shown in Figure 1c. Figure 1d shows the structure after the silicon oxide auxiliary film 5 has been etched out under the polysilicon film 10 through the etch channels 6, so that a cavity 15 has been produced between the polysilicon film 10 and the silicon base 1. An insulating film 11, preferably of silicon nitride, which also seals the etch channels 6 is deposited over this structure.

Figure 1e shows the final structure of the sensor element. Arranged on the insulating film 11 in the region of the cavity 15 are a heating resistor 21 and a temperature-dependent sensor resistor 22. The resistors 21 and 22 can advantageously be produced in the form of doped polysilicon films. As a protection against external effects and against contamination, a passivating film 12 has been deposited over the entire arrangement. Suitable

passivating films 12 are, in particular, silicon nitride or silicon oxynitride films.

Depending on the nature of the structured silicon oxide film, i.e. depending on whether it is a thermal oxide or an oxide film deposited from a silane/oxygen atmosphere, the process shown in Figures 1a to d produces membranes 20 corresponding to Figure 1e or Figure 2. The silicon base 1 in Figure 1e is not structured; the cavity 15 between the membrane 20 and the silicon base 1 is produced because the membrane 20 is formed into a dome in the manner of a bubble on the silicon base 1, as it is produced if an oxide film deposited from a silane-oxygen atmosphere is used. The silicon base 1 in Figure 2 has a recess across which the membrane 20 is stretched, so that the cavity 15 is produced by sealing the recess in the silicon base 1. This structure can be produced if thermal oxide is used. In the sensor structure corresponding to Figure 2, it is advantageous that the sensor surface is relatively flat.

In Figure 3a, 1 denotes a first silicon base into whose surface a recess 16 has been introduced. A silicon oxide film 18 has been deposited on the surface of a second silicon base 2. The arrow indicates that the second silicon base 2 is bonded to the structured surface of the first silicon base 1. This takes place via the silicon oxide film 18. After bonding, the entire silicon base 2 is removed in an etching process except for a thin silicon film 30. Into the latter a heating resistor 21 and a temperature-dependent sensor resistor 22 are then introduced by doping, as shown in Figure 3b. The silicon film 30 is then etched away with the exception of the resistors 21 and 22. Alternatively, the resistors 21 and 22 can also be introduced into the silicon base 2 for this purpose before bonding. Figure 3c shows the structure of the sensor element produced in this process. The recess in the first silicon base 1 is sealed by the silicon oxide film 18 which originates from the second silicon base 2, so that a cavity 15 is produced. The

resistors 21 and 22 which are not removed during the etching process are arranged on the silicon oxide film 18. The entire sensor surface is covered with a passivating film 12 which serves as protective film against external effects, in particular contamination or attack by aggressive media. In this structure, the membrane 20 is essentially formed by the silicon oxide film 18. The resistors 21 and 22 are composed in this case of doped single-crystal silicon.

In Figures 4a and b, a process is described which is similar to the process for constructing the sensor element shown in Figures 3a to 3c. A recess 16 is again introduced into a first silicon base 1. Passivating film 12, preferably a silicon nitride, silicon oxide or even a silicon oxynitride film, is deposited on the surface of a second silicon base 2. Resistors 22 and 21 in the form of doped polysilicon films are then deposited on the second silicon base 2. Finally, a silicon oxide film 18 is applied to the prepared surface of the second silicon base 2. The second silicon base 2 is now bonded against the first silicon base 1 exactly as in the process described above, so that the recess 16 in the first silicon base 1 is sealed to form a cavity 15. In a subsequent etching step, the entire silicon base 2 is etched away. In this process it is no longer necessary to apply a further passivating film to the sensor element surface since the passivating film 12 takes over the function of a protective film. In addition, this sensor has an unstructured surface, and this reduces the deposition of particles and the swirling of the medium.

Since the sensor elements shown in Figures 1 to 4 also act as pressure sensors, it is expedient to arrange next to the actual sensor element a further sensor element which is constructed in the same manner as the actual sensor element, but has only at least one temperature-independent sensor resistor so that it only determines the pressure but not any temperature effects. This correction parameter for the pressure can be

subtracted from the signal of the actual sensor element whose resistors are temperature-dependent.

Figure 5 shows the structure of a sensor element whose membrane 20 does not adjoin a sealed cavity. The silicon base 1 has a rear-side etching 17 which completely penetrates the silicon base 1 so that a pressure equalisation exists between the two sides of the sensor element. This structure suppresses interfering effects due to pressure differences.

Claims

1. Sensor for measuring the velocity or flow rate of a flowing medium, in particular a gas, having a sensor element, exposed to the flowing medium, with a membrane which has a resistor arrangement comprising at least one heating resistor and at least one temperature-dependent sensor resistor, the at least one sensor resistor being a component of an evaluation circuit, characterised

- in that the sensor element has a silicon base (1),
- in that a sequence of thin films (10, 11, 12; 18, 12) in which the membrane (20) is constructed is applied to the silicon base (1),
- and in that a cavity (15) exists between the membrane (20) and the silicon base (1).

2. Sensor according to Claim 1, characterised

- in that the at least one heating resistor (21) and the at least one sensor resistor (22) are arranged next to each other on a film (11; 18)
- and in that said film (11; 18) is composed of electrically insulating material.

3. Sensor according to Claim 1, characterised

- in that the at least one heating resistor and the at least one sensor resistor are arranged above each other on two different films
- and in that between the at least one heating resistor and the at least one sensor resistor there is at least one film of electrically insulating material.

4. Sensor according to Claim 1, characterised in that the heating resistor and sensor resistor are identical.

5. Sensor according to one of the preceding claims,

characterised

- in that at least one film (12) of electrically insulating material which completely covers the resistors (21, 22) is applied to the films (11; 18) on which the at least one heating resistor (21) and/or the at least one sensor resistor (22) are arranged.

6. Sensor according to one of the preceding claims, characterised

- in that the resistors (21, 22) are composed of doped single-crystal silicon or of doped polysilicon.

7. Sensor according to one of the preceding claims, characterised

- in that the films of electrically insulating material are preferably composed of silicon nitride, silicon oxynitride or silicon oxide and said films are deposited in a low-stress manner.

8. Sensor according to one of the preceding claims, characterised

- in that a polysilicon film (10) is formed into a dome in bubble fashion on the silicon base (1),
- in that a first electrically insulating film (11) is applied to the polysilicon film (10)
- and in that the resistor arrangement is applied to the first electrically insulating film (11).

9. Sensor according to one of Claims 1 to 7, characterised

- in that the silicon base (1) has a recess (16),
- in that a polysilicon film (10) which seals off the recess (16) is applied to the silicon base (1),
- in that a first electrically insulating film (11) is applied to the silicon film (10),
- and in that the resistor arrangement is applied to the first electrically insulating film (11).

10. Sensor according to one of Claims 1 to 7, characterised

- in that the silicon base (1) has a recess (16),
- in that a first electrically insulating film (18),

preferably a silicon oxide film, which seals off the recess (16) is applied to the silicon base (1),

- and in that the resistor arrangement is applied to the first electrically insulating film (18).

11. Sensor according to one of the preceding claims, characterised

- in that the silicon base (1) has a rear-side opening (17) so that the silicon base (1) is completely pierced in the region of the membrane (20).

12. Sensor according to one of the preceding claims, characterised

- in that a further sensor element having a membrane is present which is exposed to the flowing medium, the membrane of the further sensor element having at least one temperature-independent sensor resistor for determining pressure.

13. Process for producing a sensor according to Claim 8 or 9, characterised

- in that an SiO_2 film (5) structured in plinth fashion is introduced into a surface and/or applied to a surface of the silicon base (1),
- in that a polysilicon film (10) is deposited on the surface of the silicon base (1) over the SiO_2 film (5) structured in plinth fashion,
- in that etch channels (6) are introduced into the polysilicon film (10) in the region of the SiO_2 film (5) structured in plinth fashion,
- in that the polysilicon film (10) is underetched through the etch channels (6) by etching away the SiO_2 film (5) formed in plinth fashion,
- in that a first electrically insulating film (11) is deposited on the polysilicon film (10),
- in that the resistor arrangement is applied to the first electrically insulating film (11)
- and in that at least one electrically insulating passivating film (12) which completely covers the resistor arrangement is applied to the first electrically insulating film (11).

14. Process according to Claim 13, characterised
- in that the structured SiO_2 film (5) is produced by depositing SiO_2 in a silane/oxygen atmosphere.

15. Process according to Claim 13, characterised
- in that the structured SiO_2 film (5) is produced by thermal oxidation of the masked surface of the silicon base (1).

16. Process for producing a sensor according to Claim 10 or 11, characterised
- in that a recess (16, 17) is preferably etched into at least one surface of a first silicon base (1),
- in that an insulating film (18), preferably an SiO_2 film, is deposited on a surface of a second silicon base (2),
- in that the first silicon base (1) is bonded against the second silicon base (2) via the insulating film (18),
- in that the entire second silicon base (2) is then etched away with the exception of a thin silicon film (30)
- in that at least one heating resistor (21) and at least one sensor resistor (22) is [sic] introduced into the thin silicon film (30) by doping,
- in that the thin silicon film (30) is etched away except for the at least one heating resistor (21) and the at least one sensor resistor (22)
- and in that at least one electrically insulating passivating film (12) which completely covers the resistors (21, 22) is applied to the SiO_2 film (18).

17. Process for producing a sensor according to Claim 10 or 11, characterised
- in that a recess (16, 17) is preferably etched into at least one surface of a first silicon base (1),
- in that a first electrically insulating film (12) is deposited on a surface of a second silicon base (2),
- in that a resistor arrangement, preferably of polysilicon, is applied to the first electrically

insulating film (12),

- in that a further electrically insulating film (18), preferably an SiO_2 film, is deposited on the first electrically insulating film (12) and over the resistor arrangement,
- in that the first silicon base (1) with a structured surface is bonded against the second silicon base (2) via the SiO_2 film (18)
- and in that the entire second silicon base (2) is then etched away.

18. Any of the sensors substantially as herein described with reference to the accompanying drawings.

19. Any of the processes for producing a sensor substantially as herein described with reference to the accompanying drawings.

Patents Act 1977
Examiner's report to the Comptroller under Section 17 (The Search Report)

Application number

9126769.0

Relevant Technical fields

(i) UK Cl (Edition K) G1N (NAEQ NAGB)

(ii) Int Cl (Edition 5) G01F 1/68

Search Examiner

M G CLARKE

Databases (see over)

(i) UK Patent Office

(ii)

Date of Search

19 MARCH 1992

Documents considered relevant following a search in respect of claims 1-19

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
X	EP 0319871 A1 (HONEYWELL INC) Whole document	1, 2, 5, 7, 10
X	WO 89/05963 A1 (SIEMENS-BENDIX) Whole document	1, 2, 4, 5
X	US 4867842 (ASSIGNED TO HONEYWELL INC) See especially Figures 1-3	1, 2, 5, 7, 10
X	US 4501144 (ASSIGNED TO HONEYWELL INC) See especially Figures 1-3	1, 2, 5, 7, 10

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Category	Identity of document and relevant passages	Relevant to claim(s)

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

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