AMS 4711 – media compatible pressure transmitter for industrial applications in matchbox format

There is a general belief that piezoresistive pressure sensors are not suitable for measuring pressure in liquids e.g. for liquid level measurement. Taking the example of pressure transmitter AMS 4711 [1] the following article shall illustrate that this problem has now largely been solved by using modern materials and underside pressurization.

Figure 1: *AMS 4711 in matchbox format*

The problem: Media incompatibility

Standard piezoresistive pressure sensors can only measure pressure in dry, non-aggressive air, thus heavily limiting the range of application. In order to understand that these sensors can also be used for measurement in liquids and gaseous, moist media, it is necessary to take a closer look at the construction of silicon sensors.

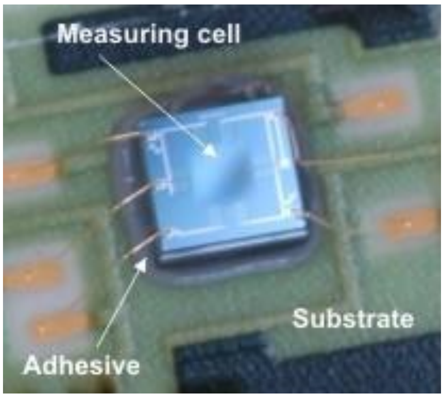

Figure 2: *silicon sensing element bonded to a ceramic substrate*

Normally, silicon sensing elements (*Figures 3 and 4*) are bonded to a ceramic substrate and pressure is applied to the upper side of the sensing element (*Figure 2*). This strengthens the bonding of the sensing element on the substrate.

Under this condition the equation $P_1/P_2 \geq 1$ applies to differential and relative sensors (see *Figure 3*).

For the purpose of bonding the topside of the silicon sensing element has several small metal surfaces made of refined aluminum known as bond pads, shown as light squares on the edge of the chip surface in *Figures 2 and 3*. These are not resistant to corrosion, however. Fine gold wires (bond wire) are attached to these pads,

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connecting the sensing element to the ceramic substrate. To protect these bond pads against corrosion (media impact), dust, and contact, the entire sensing element is then usually covered with soft silicone gel.

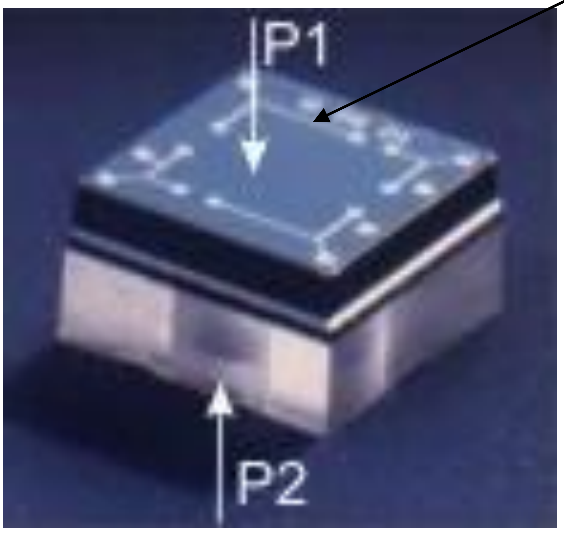

Figure 3: *differential silicon pressure sensing element (2 x 2 x 0.8 mm³) composed of microelectromechanical element (MEMS) and Pyrex socle with implanted resistors (non visible)*

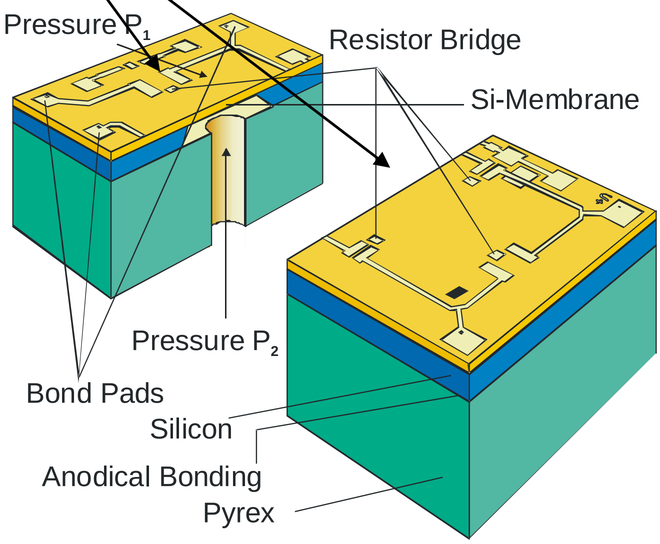

Figure 4: *section of a differential silicon pressure sensing element with a resistor bridge circuit*

There are substance-specific silicone gels available that provide good protection against watery solutions, oils or alcohols, and that prevent materials from being infused by such media, for example. There is, however, no gel that ensures universal protection against all media. The protective cover must thus be adapted to suit the application on hand. Despite this, permanent media protection cannot be guaranteed for the sensor's full lifetime, especially with media made up of more than one component.

Another disadvantage of gel material is its hygroscopic behavior. Through direct contact with liquids moisture is stored in the gel that in time can seep through to the silicon layer. This particularly applies to applications in the upper pressure range. This moisture not only causes corrosion, as mentioned above, but also a high impedance between the bond pads connected at various potentials, thus distorting measurements.

For the reasons given above, in classic assembly sensing elements without a gel protection can only be used to measure dry, non-aggressive gases, such as dry air, for example.

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The solution: Underside pressurization

The obvious disadvantages of silicon sensors can, however, be sidestepped for the media compatibility required here. One method is to mount the sensing element in an oil-filled capsule and protect this against the media with a stainless steel membrane, which incurs considerable extra cost. Another method is to apply the pressure encumbered by media to the non-sensitive underside of the sensing element (underside pressurization).

The reverse of the silicon sensing element (underside in *Figure 3*) is much less media sensitive, thus in theory providing better protection, as unlike the topside it has no aluminum bond pads. The only materials to come into contact with the measurement media are silicon oxide, Pyrex glass, ceramic, and silicone adhesive in a narrow joining gap. Thus if pressure is applied to the underside where critical media are used, neither does corrosion occur nor are there electrical short circuits.

For the sensing element, applying pressure to the underside of a differential pressure sensor means that effective (higher) pressure P_2 (*Figure 3)* is applied on the reverse. The condition $P_1/P_2 \geq 1$ thus changes to $P_2/P_1 \geq 1$, resulting in the membrane deflection being reversed and the differential bridge signal polarity changing (see *Figure 5*).

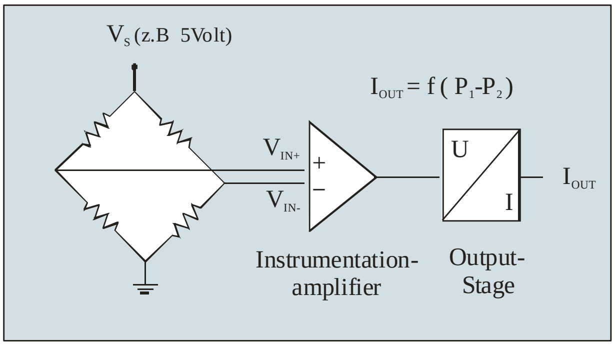

Figure 5: *circuitry of a piezoresistive pressure sensor*

At the negative input of the instrumentation amplifier there would then be a higher value present than at the positive input, meaning the amplifier has a negative input signal. If the polarity of the instrumentation amplifier would be changed so it amplify in the given, correct manner.

With underside pressurization and the reverse polarity of the instrumentation amplifier, in principle pressure can be measured in liquids and gases, a feat which is not possible in the long term with the usual topside application of pressure.

The disadvantage of the method described above is that higher pressure P_2 antagonizes the adhesive joint. The join of the Pyrex and the ceramic substrate (see *Figure 2*) must thus demonstrate a secure mechanical bond even when positive pressure is applied. With modern adhesives, this is a question of materials and adhesive technology.

Media resistance of AMS 4711

The underside pressurization method has been consistently applied to AMS 4711 [1]. The pressurized medium thus only has direct contact with the ceramic substrate, the Pyrex base, the silicon sensing element, and the adhesive joint between the Pyrex base and silicon sensing element. In addition to these contacts, the materials of the housing and pressure lines play an important role in the media sensitivity of the sensors.

In AMS 4711 the media-carrying connection nodes with their pressure distribution cap consist of robust PA 66[1], with the substrate and protective cap (see *Figure 6*) made of non-sensitive AL_2O_3.The ceramic substrate, Pyrex base, and silicon are chemically resistant to most media

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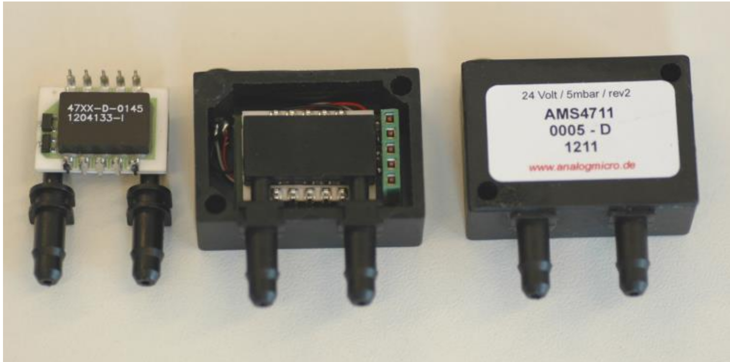

Figure 6: *AMS 4711 sensor and interior*

except very aggressive acids and bases. The adhesives themselves that are used to stick the connection nodes and cap and the protective ceramic cover to the substrate, plus the adhesive join between the ceramic substrate and Pyrex base, could cause problems with various media. In cases such as these the answer is to use select materials for bonding that are media resistant and strong enough to withstand underside pressurization.

[1] PA 66 is resistant to aliphatic and aromatic hydrocarbons, alkalis, brake fluids, esther greases, ketones, fuels and coolants, solvents, cleaning agents, and detergents, oils, fats, alcohols, and water, among other substances.

Description of AMS 4711

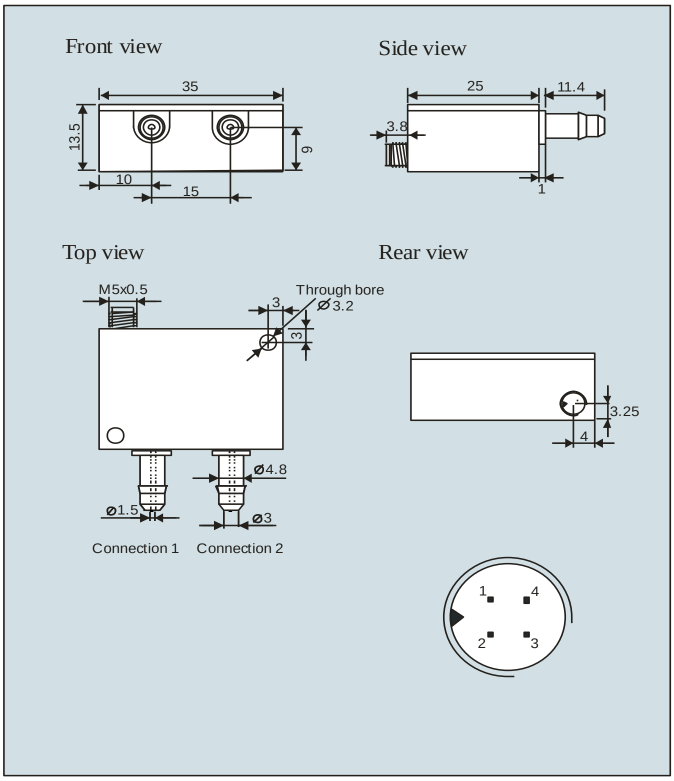

Figure 7: *Dimensionen in mm*

The miniaturized pressure transmitters in the AMS 4711 [1] series are high-precision, ready-to-use pressure sensors (transmitters) with a voltage output of 0 … 5 V. The sensors are calibrated, compensated for, and linearized for use in the industrial temperature range of -25 … +85°C. The supply voltage can range from 7 to 36 V.

In both its differential and relative versions AMS 4711 has two side hose connections and just one connector on the absolute model (4.8 mm diameter).

Electrical connection is through an M5 sensor plug connector. The sensors comply with IP Code IP 67 and are suitable for the most outdoor applications.

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AMS 4711 are available in pressure ranges of 0–5 mbar to 0–350 mbar for differential/relative applications and in the range of 0–1 bar and 0–2 bar for absolute or differential/relative pressure measurements. There is also a bi-directional, differential versions supplied in the ±5, ±10, ±20, ±50, and ±100 mbar ranges which allows the measurement of under- and over pressure.

The absolute pressure version for 700 – 1200mbar is especially for barometrical applications.

AMS 4711 has underside pressurization as a standard and is thus suitable for measuring pressure in a number of different liquids and reactive gases for e.g. industrial, medical and HCAC-applications.

Applications

The AMS 4711 is suitable as a relative version for level sensing in open containers. As a differential sensor it can be used for level control in pressure tanks. Due to its high sensitivity, exhaust and feed controls are already possible for small quantities of liquid [2].

Summary

Underside pressurization relieves the limited use of piezoresistive silicon pressure sensors in dry and non-aggressive gases only.

As the rear side of the measuring cell of the sensor is much less media-sensitive than the front side, pressure transmitters such as the AMS 4711 can even be used in liquids up to a certain overpressure by pressurizing the back and reversing the instrumentation amplifier.

Further information

[1] Product information AMS 4711: https://www.amsys-sensor.com/products/pressure-sensor/ams4711-analog-pressure-transmitter-5v-output/

[2] Level sensing with AMS 4711: https://www.amsys-sensor.com/downloads/notes/ams4711-precise-level-sensing-with-a-low-pressure-transmitter-amsys-522e.pdf

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