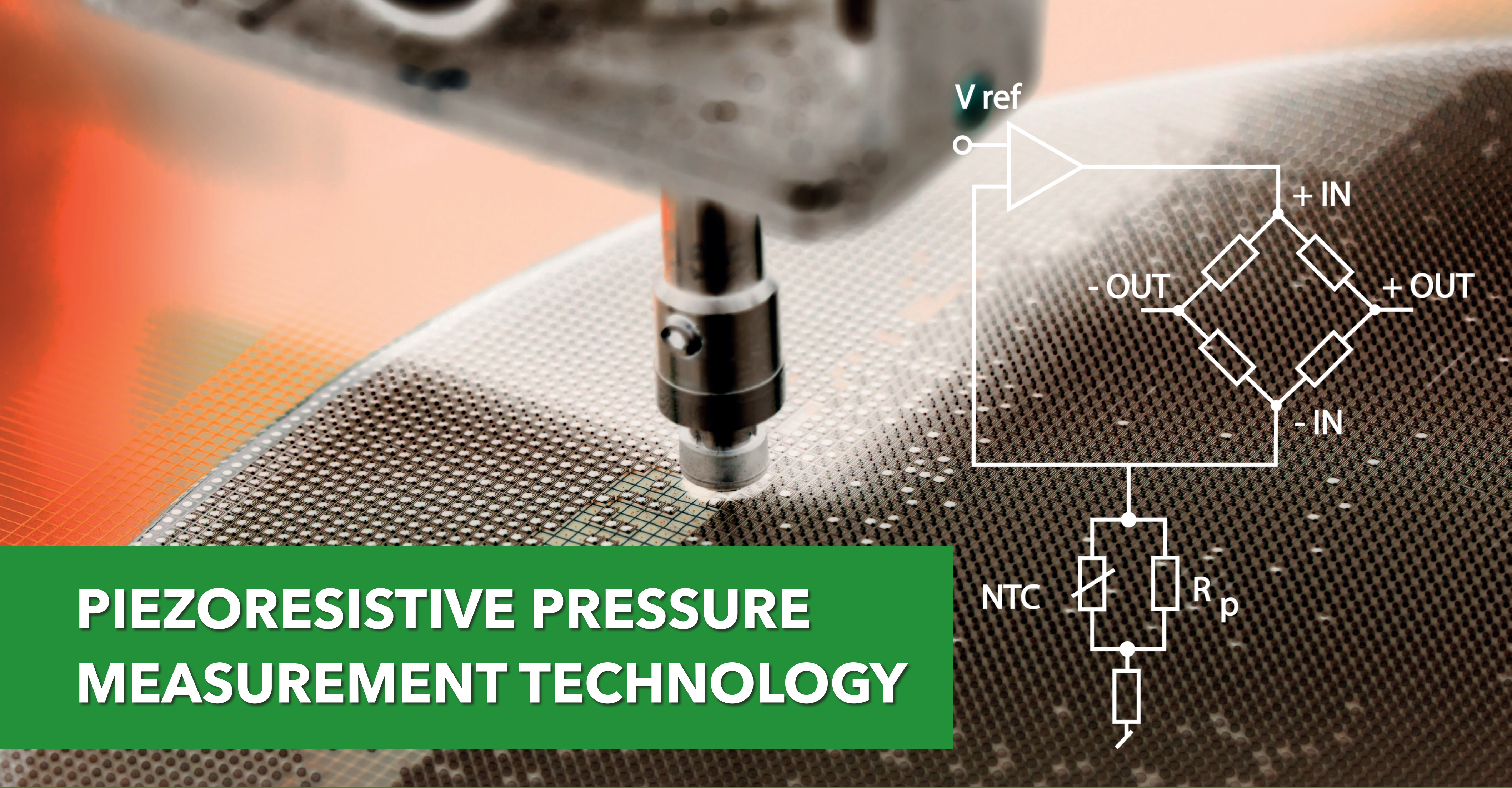

PIEZORESISTIVE PRESSURE MEASUREMENT TECHNOLOGY

Piezoresistive technology is often mentioned in the same breath as pressure measurement. But what exactly is the piezoresistive effect? And why is this technology used in pressure measurement?

Along with temperature, pressure is an essential parameter in many technical systems. In addition, a wide variety of industrial processes require precisely controlled pressure conditions. That's why, besides temperature measurement, pressure measurement is the most important and most frequently used technology for monitoring and controlling machines and plants. For this, the atmospheric air pressure is an important environmental variable and, by measuring the gravitational pressure of the liquid column, for example, groundwater levels or fill levels can be determined.

Electronic pressure measurement requires a sensor that records the pressure to be measured and converts it into an electrical signal. Resistive pressure measurement centres around an electrical resistance whose resistance value changes as a function of the pressure to be measured.

Resistive pressure measurement

In the simplest case, classic resistive pressure measurement works with a thin strip of metal whose resistance value changes when deformed. When stretched, the strip becomes longer and thinner, increasing its electrical resistance; when compressed, the strip becomes shorter and its cross section increases, thus decreasing its resistance. In order to translate the pressure to be measured into a controlled mechanical deformation, a strain gauge is applied to an elastic membrane. Normally, this is connected using adhesive. If pressure then acts on one side of this membrane, it deforms and, depending on the position of the strain gauge on the membrane, results in it being compressed or stretched (see Figure 1). The greater the pressure, the more the membrane deforms, meaning that the extent of the change in resistance depends directly on the pressure. For a more accurate measurement, several strain gauges are combined into a bridge circuit and the resistance change is recorded as a voltage signal.

Piezoresistive pressure measurement

Derived from the ancient Greek word piezein (meaning to squeeze or press), piezoresistive technology is a process that works using pressure. The basic principle of piezoresistive pressure measurement essentially corresponds to that of resistive pressure measurement. Here too, extension or shortening causes a change in resistance. In addition, in a piezoresistive material, however, the mechanical tension that occurs when it is stretched or compressed also leads to a change in electrical conductivity. This piezoresistive effect is based on shifts in the atomic positions, which directly affect the electric charge transport. The change in resistance resulting from the change in electrical conductivity can be significantly greater than that caused by pure deformation.

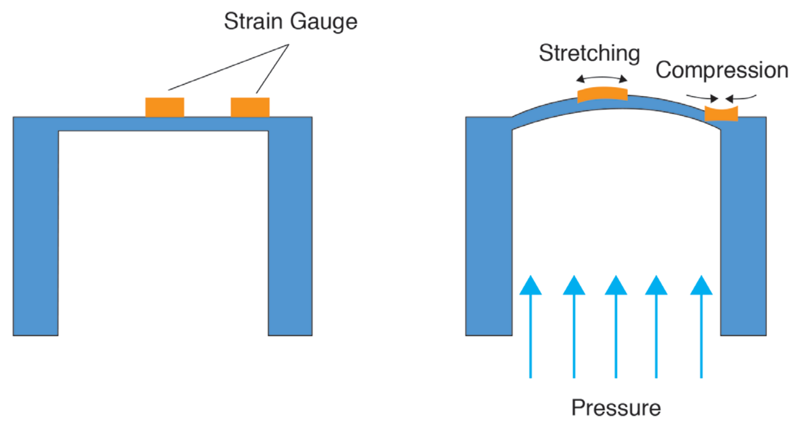

Figure 1: Positioning of strain gauges on a pressure-sensitive membrane.

Typical piezoresistive materials that exhibit a strong piezoresistive effect are semiconductors. These are materials whose electrical conductivity is between that of electrical conductors (metals such as silver, copper and aluminium) and nonconductors (such as glass). Silicon is typically used to make piezoresistive pressure cells, and is also is used in the production of electronic circuits. The sensors made from this are therefore also referred to as sensor chips.

The basis for piezoresistive sensor chips are crystalline silicon discs less than one millimetre thick known as wafers (see Figure 2). Foreign atoms are introduced in the surface at certain points, which locally influence the conductivity. This process is called doping, and these doped areas in the silicon form the piezoresistive resistors. In a subsequent step in the process, the silicon wafer is then thinned on a localised basis in such a way that membranes are formed directly in the silicon and the piezoresistive resistors lie in certain positions, similar to that shown in Figure 1. If any pressure then acts on one side of this membrane, it deforms and thus causes a mechanical stress in the piezoresistive resistors. Depending on the position, the resistance value then increases or decreases. The pressure sensitivity of the sensor chip can be adjusted through the thickness of the remaining membrane.

Afterwards, the back of the silicon is firmly connected to a glass (see Figure 3). For absolute pressure sensors, this creates a closed reference space in a vacuum. When measuring relative pressure, the rear glass contains a reference hole. In piezoresistive pressure measuring cells, unlike in strain gauges, the measuring resistors are therefore integrated in the membrane. This technology thus eliminates the need for gluing and thus the weak point, namely the adhesive, which is an important prerequisite for resistance to ageing and temperature as well as freedom from hysteresis (hysteresis = after-effects of the previous deformation state). In addition, the piezoresistive effect leads to a change in resistance up to 50 times greater than can be achieved with metallic strain gauges.

In order to isolate the sensor chips from the medium to be measured, they are mounted in a pressure-tight metal housing which is filled with oil and sealed at the front with a thin membrane (see Figure 4). The pressure then acts on the sensor chip via this membrane and the oil as a transmission medium. Pressure measurement is also possible with this isolated measuring cell in aggressive liquids and gases.

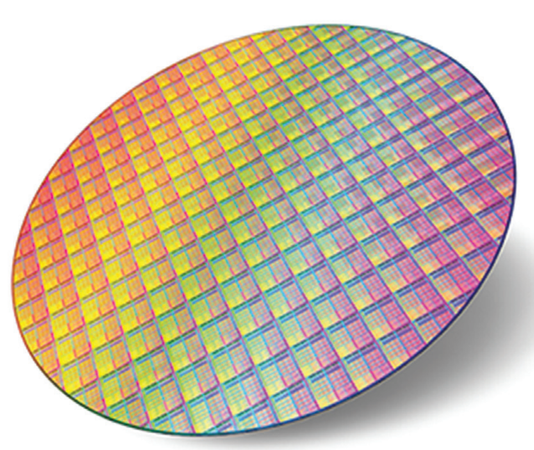

Figure 2: Silicon wafer on which various metal structures are applied

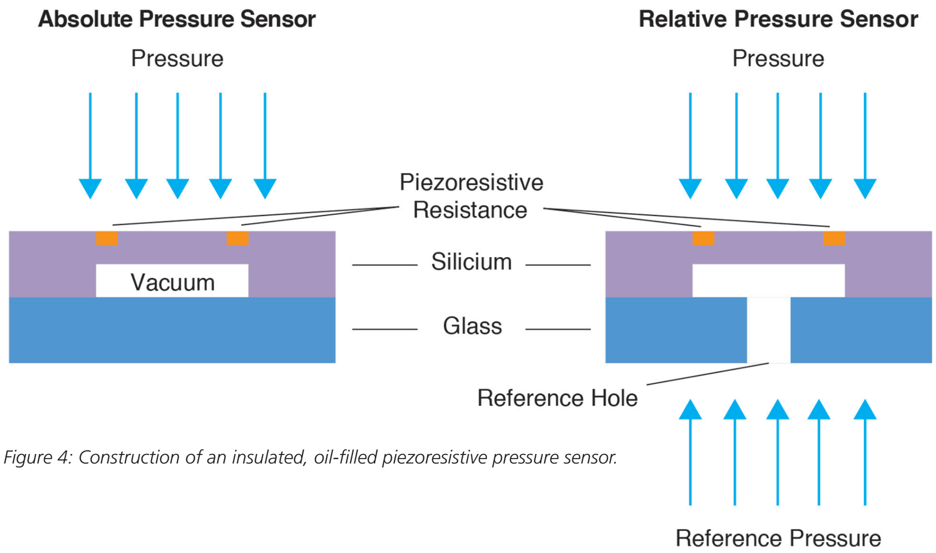

Figure 4: Construction of an insulated, oil-filled piezoresistive pressure sensor.

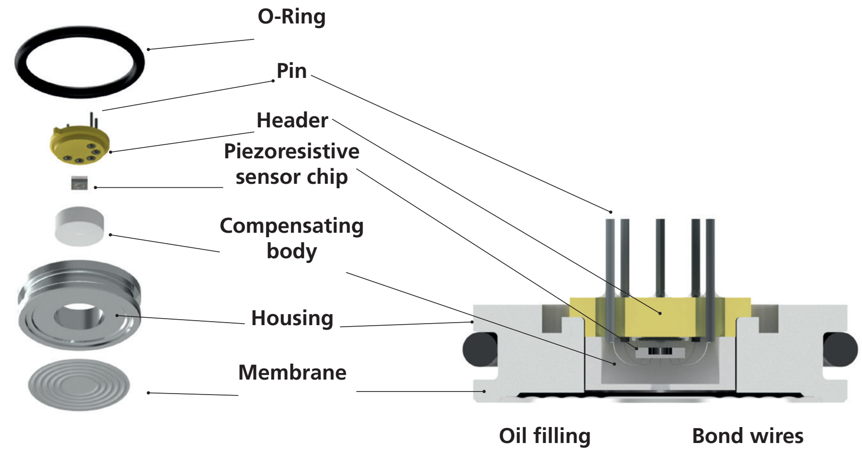

Figure 3: Structure of a piezoresistive sensor chip.

Why use piezoresistive technology in pressure -measurement?

Due to the large output signal and the established manufacturing processes, piezoresistive technology has become established in pressure measurement. Another major plus point is that there is no need to glue the strain gauge, which is critical for stability.

The crystalline silicon of the sensor chip deforms in a purely elastic way during operation, so no signs of fatigue or stability problems occur, even after many pressure cycles. The sensor chips can be produced in established electronic semiconductor technology processes, and integrating the relevant membrane for pressure measurement into the sensor chip allows for the manufacture of extremely compact and long-term stable pressure measuring cells. As piezoresistive pressure transducers are built without moving parts, they are very resilient against shocks and accelerations. The much greater change in resistance in piezoresistive measuring cells compared to conventional metal strain gauges leads to a large output signal and thus allows for a low-noise electronic evaluation with high resolution. In combination with analogue or digital compensation solutions, an extremely precise, temperature-independent pressure signal is thus available.

The isolated piezoresistive pressure measuring cell stands out thanks to its versatility: it is compatible with various media and covers wide pressure ranges. The specific construction of the housing achieves great flexibility for many industrial applications, even in critical environments. What makes KELLER AG für Druckmesstechnik stand out is the essential knowledge of designing and manufacturing isolated measuring cells. Thanks to

45 years of experience in piezoresistive pressure measurement, the company can also expertly implement special applications. Insulated piezoresistive pressure cells from KELLER AG für Druckmesstechnik are used in demanding industrial applications and in research.

Advantages and disadvantages of piezoresistive technology

- \+ Established processes in the production of piezoresistive sensor chips, long experience with piezoresistive technology
- \+ Coverage of wide pressure ranges
- \+ Very good long-term stability
- \+ No signs of fatigue, even after many pressure cycles
- \+ High overload resistance
- \+ No hysteresis of the silicon sensor chip
- \+ Compact pressure measuring cells
- \+ Good shock and vibration resistance
- \+ Suitable for measuring relative and absolute pressures
- \+ Isolated measuring cell for wide range of media compatibility
- \+ Can be used in a variety of industrial applications
- \+ Large output signal allows for simple read-out electronics with high resolution
- • Temperature compensation required
- • Designing and manufacturing the isolated measuring cell requires a lot of expertise
- – Measurement of very small pressures limited (< 0,01 mbar)
- – Additional measures required at very high media temperatures (> 200 °C)

Author Contact Details

Dr. Sören Boyn, KELLER AG für Druckmesstechnik • St. Gallerstrasse 119, CH-8404 Winterthur
• Tel. +41 52 235 25 25 • s.boyn@keller-druck.com • **Web: www.keller-druck.com**