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Highly stable pressure sensors made of <110> silicon

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Summary:
A pressure sensor chip of <110> p-silicon is described. The piezoresistive measuring resistors run, in <110> direction. They have only a noticeable longitudinal effect. This is the first prerequisite for an ideal mirror-image arrangement of a measuring bridge. Thus it is possible to achieve an ideal symmetrical change in resistance due to the compressive load. These sensors were manufactured, the effectiveness is presented.

Keywords: silicon, piezoresistive, pressure sensor, stability, linearity

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For miniaturized sensors based on silicon and MST technologies, the piezoresistive measuring principle has proven to be versatile and robust. The measuring principle is of great importance for pressure sensors. The basic structure of silicon-based, piezoresistive pressure sensors is well known. The integrated piezoresistive measuring resistors react to strain or mechanical stress. Therefore, they are integrated in a bending plate, which changes its mechanical stress state pressure-dependent in a very selective way. The measuring resistors are arranged as a measuring bridge to increase the sensitivity and to compensate the temperature dependence.

For high-precision pressure measuring cells, the effort for calibration over the entire application range is approx. 20-30 % of the manufacturing costs. Especially the nonlinear dependencies of the measurement signal on pressure and temperature lead to this high effort. Thus these costs exceed the chip price many times over. Therefore it makes sense to reduce especially these costs. If e.g. the linearity is increased, a reduction of the degree of the polynomial, this expenditure is reduced substantially. This means there are less calibration points, less pressure-temperature pairs, necessary for calibration. Further possibilities are to reduce the effort for signal processing:

- Temperature coefficient of the zero point
- Temperature coefficient of the measuring span
- Influence of the mechanical mounting stresses

One starting point is the optimization of the measuring bridge, which means that an ideally designed measuring bridge compensates all influencing variables which are identical at all four measuring points. Most silicon-based, piezoresistive pressure sensors consist of p-type measuring resistors in an n-type substrate of orientation <100>. The measuring resistors are sensitive in longitudinal and transverse direction in relation to the flowing current. These properties result in the classical arrangement of the measuring resistors on the bending plate of silicon-based piezoresistive pressure sensors. Since the piezo coefficients of the magnitude are only similar and not identical in the mechanical stress field, the selection of a suitable design is accordingly complex and often cannot be optimized over the entire measuring range. This can be seen in the linearity of the pressure characteristic curve and the temperature dependence of the measuring span. In this paper an almost completely symmetric bridge design shall be investigated. For this purpose p-type measuring resistors in an n-type substrate of orientation <110> are used.

Fig. 1 shows the direction dependent piezo coefficients of <110> p-silicon, the transversal effect in direction <110> is minimal.

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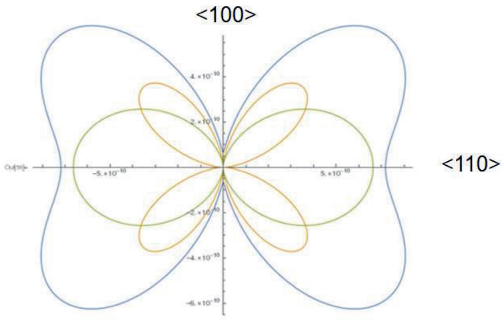

Fig. 1: Directional piezo coefficient of <110> p-silicon, longitudinal effect (σ_{xx}): $\pi_{l(110)}$ and the transverse effect (σ_{yy}): $\pi_{t(110)}$, blue: directional longitudinal effect (for σ_{xx}), orange: directional transverse effect (for σ_{yy}), green: directional transverse effect (for σ_{zz})

If the measuring resistors are oriented in the direction <110> only the longitudinal effect is effective, a completely symmetrical layout can be realized. First measurements on a demonstrator show that the system has a good linearity and a good long term stability.