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Impact of thermo-mechanical effects to the measurement behavior of a molded SO16 System-in-Package current sensor investigated by a physics-based design for reliability (DfR) approach

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In this work a physics-based design for reliability approach (DfR) is presented investigating the thermo-mechanical behavior of a AMR current measurement sensor device in a SOIC16 package. Due to the exposition to different thermal loads during production and operation the intrinsic strain values at the internal sensor cells are changing. This is suspected for a significant impact to the stress/strains at the AMR sensor cells and possibly affecting the measurement accuracy. For investigating the impact from different influences and uncertainties several simulation-based design-of-experiment (DoE) studies were performed. Beside the incorporation of effects from the material behavior, also process related parameters and tolerances were included in the virtual model. The modelling of stiffening effects caused by mold compound ageing at the outer layers during operation was also included. The generated design for reliability "environment" represents a comprehensive approach to combine production process and operation to examine possible thermo-mechanical effects during an early development stage.

Keywords: Design for Reliability, Sensitivity study, Uncertainty quantification, Design-of-Experiments, Current sensor, System-in-Package, Thermo-mechanical effects

1. Introduction and motivation

Due to the progressing electrification for future mobility applications accurate and reliable information from current sensors are essential during operation to control the complete electrical system. Harsh environmental conditions as well as specific mission profiles have to be considered during the development phase. Thermo-mechanical effects caused by temperature loads during production and operation as well as influences from design or production related tolerances could lead to unfavorable situations. Unfortunately, different aspects or quantitative influences are often uncertain at an early design stage. With the incorporation of parametric sensitivity studies and modern Computer-Aided-Engineering (CAE) methods it is possible to face these issues and achieve a deeper understanding of the later physical device behavior.

The investigated electronic device presented in this work was developed as molded SO16 System-in-Package (SiP). Based on a magneto-resistive measurement principle the AMR sensor was designed for industrial and automotive applications. Due to different process schemes during production, the strain at the internal AMR sensor surfaces are changing (see Fig. 1). Furthermore, depending on the specific mission profile the electronic device is exposed to different thermal loads during its operation. This can result in a manifestation of a sensor calibration inaccuracy affecting the overall measurement performance.

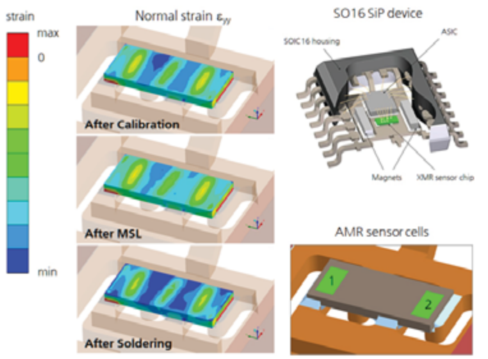

Fig. 1 Strain distribution at the AMR sensor surface during production (left) and influenced sensor areas (bottom right)

2. Physics and simulation based DfR approach

To understand the device behavior and helping to improve the later product reliability for the purposed operation environment, various aspects were incorporated in a FE simulation model. Influences from materials (Young's modulus, CTE, post mold cure shrinkage etc.) and processes (dwell temperatures and times) are important for the initial device state [1]. The production process scheme itself has also an impact on the strain changes after the calibration step (Fig. 2).

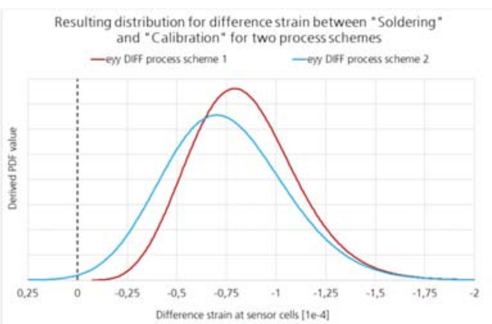

Fig. 2 Distribution of strain changes at the sensor cells after calibration for two different process schemes

Furthermore, a certain mold compound aging was recognized during reliability tests. This reflects in a growing oxidized layer at the outer surface of the molded package with changed material properties. According to literature [2], a layer based FE model approach was implemented and effects to the resulting strain values of the sensor were investigated during production and operation (see Fig. 3).

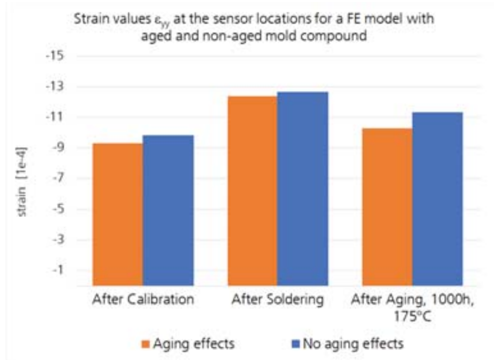

Fig. 3 Comparison of strain values caused by the incorporation of aging effects in the FE model

3. Conclusions

The presented DfR approach was developed to investigate the possible impact of specific thermo-mechanical effects to the behavior of an AMR current measurement device. It represents an appropriate method to combine influences from production process and operation (mission profile). Due to the incorporation of fluctuations and conduction of sensitivity studies it helps to understand certain reliability issues of the later product and supports major design decisions during the development early stages.

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