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# Combined simulation and optical measurement technique for investigation of system effects on components solder fatigue[☆]

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## ABSTRACT

Among others, physics of failure related concepts are being developed to address the thermo-mechanical reliability challenges in automotive electronics. Limitations in particular applied for finite element (FE-) analyses are models of limited size, which rarely address the system character of failure. Also in testing a system view on fully mounted electronic control units (ECU) and loaded by environmental and active loading cannot be taken performing end-of-life tests for time limitations. Accelerated testing is done instead, however, mostly on board level.

To overcome some of these limitations, a combined measuring-simulation technique is being developed, which is described in the paper. System level view on boards mounted in automotive ECUs is taken by a newly developed high-precision optical deformation measuring system. The multi-sensor measuring method combines a chromatic sensor for topography and warping analysis with an optical sensor for in-plane deformation and strain field analysis. By this combination, a high resolution can be reached for all three components of displacement vectors. Additionally, software tools allow the determination of derived quantities like strains, local curvatures and local warpage radius. The latter can be taken as input for FE-simulations. It is shown that some components, in particular QFNs, are sensitive to thermally induced cyclic warpage even if the corresponding bending deflections are in the micrometers range. Worst case in-plane stretching and cyclic warpage of a board mounted in an ECU have been measured. By corresponding simulations on QFN solder fatigue, mounted on a special test board, the critical fatigue life can be determined dependent on the interaction to the case, which differs by several hundred percent from a free-standing assembly.

## 1. Introduction

The continuing development of electronic systems for harsh condition applications generates various challenges, in particular also on reliable functionality. The conflicting issues cost and safety relevant use, e.g. in applications towards autonomous driving, requires also more attention to reliability prediction based upon “physics of failure” concepts. Advantages in cost and availibility can be a driving force towards the use of electronics components in automotive environments (automotive electronics, AE), which were originally designed for consumer electronics (CE) use, a subject currently under investigation in the TRACE project [1]. Electrical & thermo-mechanical reliability issues are of major concern in those applications.

Theoretical modelling has been widely used to evaluate risks of thermo-mechanical induced failure in electronic systems. However, there are still limitations in complexity of the models both in regard of system geometry, e.g. complete mounted boards, and evaluation criteria, e.g. damage mechanics.

The paper describes a methodology which combines measuring and simulation techniques for improved reliability evaluation on board and system level. The methodology is dedicated to avoidance of product functional failures because of typical automotive stresses, however, the applicibility goes beyound automotive application scenarios and consumer electronic components use.

An optical multi-sensor measurement method has been developed which is capable of precise deformation measurements of boards mounted in automotive electronic control units (ECUs) from global level to local level. The high precision, which is above the currently

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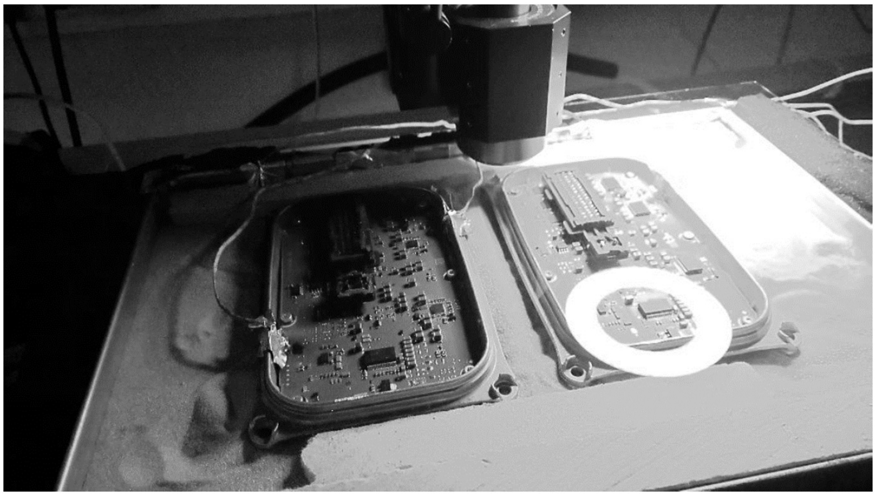

**Fig. 1.** Optical deformation analyses of an ECU subjected to temperature changes.

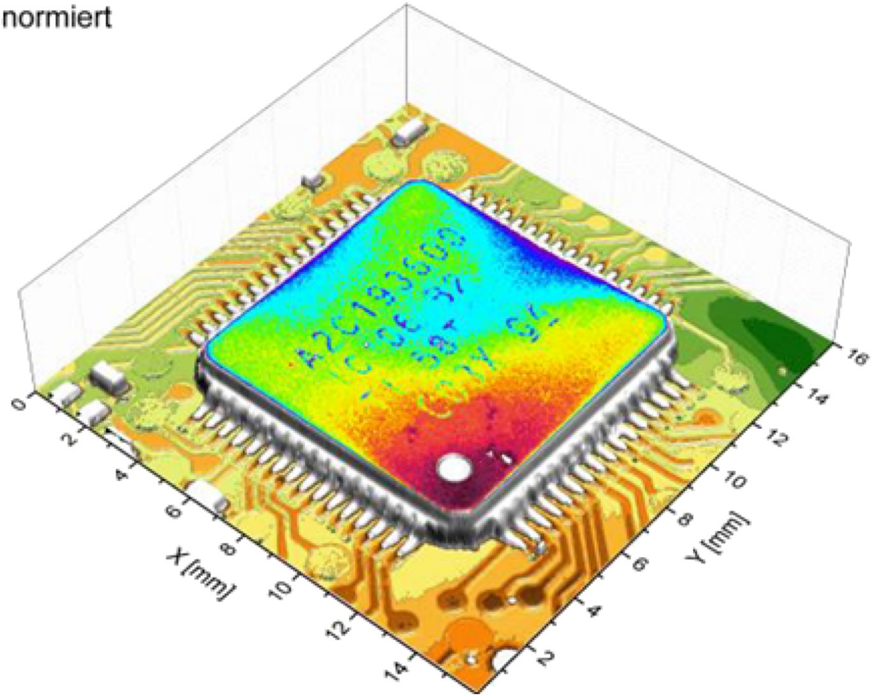

**Fig. 2.** Out-of-plane displacements (20 μm to +150 μm) of a QFN on board mounted in an ECU.

applied solutions, allows in particular the measurment of component deformation down to nanometer range under system loading conditions.

The multi-sensor measuring method combines a chromatic sensor for topography and warping analysis with an optical sensor for in-plane deformation and strain field analysis. It is based on the MicroProf optical metrology tools from FRT [2] and the digital image correlation methods developed and refind by CWM [3]. By this combination, a high resolution can be reached for all three components of displacement vectors. Additionally, software tools allow the determination of derived quantities like strains, local curvatures and local warpage radius.

By the method system effects on component level can be studied for