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# Outline of Thesis

## Thermal metrology for the reliability challenges of electronic components on next generation high power dissipating ECUs

As the development of vehicle technologies, eg. the development of autonomous driving. More power electronic components would be equipped on ECUs, including BGAs, QFNs, etc., to improve their calculation abilities. More efficient thermal management systems are required to improve the reliability of the high-power dissipating ECUs (electronic control units). There are two significant problems in the thermal design field of high-power dissipation ECUs: accurate estimation of the components' heat dissipation and sufficient solder crack detection. The two problems are investigated in this research work.

Chapter 1 outlines the background and the objective of this research. The trend and challenge of the development of the automobile industry are described. As an indispensable control module of a vehicle, the ECUs and their typical architectures are described in this chapter. Moreover, this chapter points out the reliability problems of electronic components on the next generation high power dissipating ECUs. Accurate temperature field prediction and crack detection technologies are two significant problems to improve the reliability of the components equipped on ECUs. In the current stage, using the datasheet provided by manufacturers will lead to a relative error of about ±30% of heat dissipation prediction, meanwhile, the most widely used crack detection method is the cross-section cut method which will destroy the testing component. This dissertation focuses on developing a novel heat dissipation measurement method and in-situ crack failure diagnosis method based on the theory of thermal metrology. The research could contribute to the reliability improvement of high-power dissipating ECUs in the thermal design field.

Chapter 2 describes the proposed method of heat dissipation measurement applied on a single component equipped on a PCB testing board. A one-dimensional thermal resistance network model of the system is introduced and the relative error of the proposed method is defined in this chapter. From the calculation, the heat flow through the heat flux sensor shows proportional to the heat dissipated from heat sources (die in the component or heater). The relative error is calculated to be a function of thermal resistance between heater and die in the component. The experimental setup is also introduced in this chapter, the proportional relationship between heat dissipations of heat sources and heat flows through sensors is verified from the viewpoint of the experiment. Thermal resistance between the heater and die in the component is the main reason that contributes to the relative error of the proposed method. Further, uncertainty analysis is carried out to investigate the effects of heater positions, sizes, and thicknesses of TIM on the relative error of the proposed method.

Chapter 3 describes the proposed method of heat dissipation measurement applied on multiple components equipped on ECU. Based on the theory introduced in chapter 2, the thermal resistance network model of testing board equipped with multiple components is carried out in this chapter. A matrix function is proposed to describe the relationship between the heat flows through sensors and the heat dissipations from components. The heat dissipations of the components could be obtained by solving the matrix function. Further, two algorithms of data processing methods, loose logic, and tight logic are proposed. These algorithms are used in cases with a different number of components, concretely, loose logic is used in the case when there are 4 or more components while tight logic is used in the case when there are less than 3 components equipped. In this chapter, the proposed method is applied on a testing board with 5 components and an ECU with 3 components experimentally and numerically. The proposed method could predict heat dissipations of the components on ECU within a relative error of ±10 %.

Chapter 4 describes the proposed method for solder crack failure detection of components equipped on ECU. As the thermal resistance from die in the component to the bottom of the PCB will change when a crack generates in a solder connection part. This chapter investigated the relation between the change of the described thermal resistance to the crack ratio of solder in MOSFET testing boards with different sizes in both viewpoints of experiment and simulation. In the experiment, the procedures of MOSFET sample preparation and measurement of thermal resistance from die to PCB bottom are introduced. The thermal resistances of the samples with diverse crack ratios and crack positions are tested experimentally. Meanwhile, the thermal resistances of the prepared samples are calculated by using a commercial simulation package software. Further, crack positions of a MOSFET model are changed under a certain crack ratio to calculate the thermal resistance to investigate the corresponding maximum and minimum thermal resistance under the given crack ratio. Results show that the calculated upper and lower limits can give the range of crack ratios as a function of thermal resistance. This proposed crack detection method could be served as an in-situ crack detection method in the ECU thermal design stage.

Chapter 5 summarizes the important conclusions in the research work contained in the dissertation. This chapter also proposes future work that can be done to address unsolved issues and expand the usage limits.