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Modeling and Simulation for Lifetime Predictions

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NPS NRP Executive Summary

Title: Modeling and Simulation for Lifetime Prediction

Report Date: 10/09/19 Project Number (IREF ID): NPS-19-N085-A

Naval Postgraduate School / School: GSEAS/Systems Engineering

NAVAL RESEARCH PROGRAM

NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

IMPROVING ACCURACY OF LIFETIME PREDICTIONS FOR MICROELECTRONICS USING A MERGED PROBABILISTIC PHYSICS OF FAILURE APPROACH

Period of Performance: 10/15/2018–10/14/2019

Researchers:

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EXECUTIVE SUMMARY

Project Summary

Service life assessments and reliability predictions for electronics need improvement early in the design phase to avoid the current uncertainties, inaccurate results, and poor design decisions. This research paper presents a merged probabilistic physics of failure (PoF) approach to account for the physical location of microelectronics and determine the resulting time-to-failure based on randomly placed failure mechanisms. A case study using a generic circuit card assembly and corrosion related failure mechanisms exhibits the utility of the merged probabilistic PoF approach. The results demonstrated that the location of microelectronics can impact the time-to-failure for a circuit card assembly because a failure mechanism's probability of occurrence increases or decreases based on changes in temperature and humidity. Additional research and analysis using actual test results should be performed to verify the accuracy of the results and to account for additional failure mechanism types.

Keywords: *reliability predictions, physics of failure, PoF, probabilistic, failure mechanisms*

Background

In the last few decades, there has been increased pressures on the electronics industry to increase the performance of their chips while decreasing the physical size. This results in an increased number of transistors per chip and increases the number of reliability issues primarily due to higher current densities (Varde, 2010). The increased complexity in electronic devices drives the need for more accurate and robust prediction methodologies to improve service life assessments. Traditional methods for predicting reliability or time-to-failure such as those found in MIL-HDBK-217F, notice 2, are well documented and widely used by practitioners; however, they are often inaccurate compared to the reliability of fielded devices and do not account for uncertainties. Some of the inaccuracies can be attributed to not understanding the initial source data for the application, environmental conditions, operational modes, and lack of understanding the detailed design (Gu and Pecht, 2007).

In support of improving service life assessments and reliability predictions for electronic and complex hardware systems, this research investigated the development of a model for predicting the expected life of parts. Specifically, this research uses PoF models for electronic devices, incorporates a probabilistic approach to account for the uncertainties due to variations in parameters, and accounts for the location failure mechanisms. The goal is to merge the impacts due to multiple failure mechanisms and improve the accuracy of the service life assessment. For purposes of this research, PoF is based on principles of science and technology and provides the insight into not only life and reliability aspects of the component but also provides details about the various degradation mechanism(s) and thereby improved understanding of the associated root cause(s) of the failure

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Findings and Conclusions

This research can help the Navy and design engineers by providing a methodology and process to predict where failure mechanisms are more likely to occur and improve the service life and time-to-failure for microelectronics early in the design phase. The merging of the two or more failure mechanisms is only practicable if they occur in the same location.

The first step of the process was to identify the potential failure mechanisms based on the operational modes and environment. For example, we chose to assume that corrosion and electromigration were likely to occur based on high temperatures (e.g. >85°C) and relative humidity levels in excess of 85%. Typical operating temperature ranges for military electronics is -65°C to +125°C. Given the assumed failure mechanisms, the likely locations of occurrence were identified on the circuit card assembly, which allowed the area of the circuit card assembly to be randomly sampled for thousands of iterations using a Monte Carlo simulation. The results from the simulation were analyzed and the number of cases where one or more failure mechanisms were present was determined. When multiple failure mechanisms were found, the resulting time-to-failures were merged. Based on experience, simply adding the time-to-failure for two failure mechanisms seems to be too conservative but is typically preferred over being overly optimistic, which could result in a large logistics burden.

The results demonstrated that the location of components can significantly impact a circuit card assembly's service life due to an increased likelihood of one or more failure mechanisms. From a design perspective, if the operational environment (e.g. stressors) and likely location of failure mechanism occurrence is understood upfront and early in the design, the time-to-failure or service life can be significantly increased.

Recommendations for Further Research

Further research and analysis based on actual test results is required to better understand the likelihood of multiple failure mechanisms occurring within the same region or location of a component or device. The data would allow for more experimentation to determine if one or more failure mechanisms are likely to occur within the same location or region, and increase the confidence of merging results. Additionally, there needs to be more experimentation to determine the optimal method for combining failure mechanisms. For example, it may not be optimal to add the time-to-failures for multiple failure mechanisms. It may be more realistic to use a weighted average based on their likelihood of occurrence.

References

Varde, P. V. (2010). Physics-of-failure based approach for predicting life and reliability of electronics components. *Barc Newsletter*, *313*.

Gu, J., & Pecht, M. (2007, August). Predicting the reliability of electronic products. In *2007 8th International Conference on Electronic Packaging Technology* (pp. 1-8). IEEE.

Acronyms

Physics of Failure	PoF