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MEMS Reliability Assurance Guidelines for Space Applications

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Preface

This guideline was developed as an aid to help in the understanding of Microelectromechanical Systems (MEMS) reliability and to facilitate the insertion of this technology into high reliability applications. Modeled after the GaAs MMIC Reliability Assurance Guideline for Space Applications by Kayali et al., it was felt that a guideline would be more advantageous to people than a strict specification. With the MEMS industry as diverse as it is today, it seemed presumptuous to lay out specific tests for every MEMS device inserted into space as that kind of document would be unduly constrictive to some applications. Rather this document was intended as a MEMS educational guide, offering descriptions of the most common devices and technologies and the steps required to meet the demands of the space environment.

The focus of this guide is upon methods rather than tests and as such, it is assumed that the ultimate responsibility for reliability lies in the hands of the user. Ultimately it is felt that the designers and the customers will have to reach an understanding as to the exact qualification needs of a particular device.

The guideline begins with a chapter on the recent developments in the field of MEMS and the need for an understanding of related reliability issues. Chapter 2 offers a basic review of reliability models and of semiconductor failure distributions. This chapter is intended to aid the reader in understanding the meaning of reliability tests in general, and how they may apply to MEMS.

Chapter 3 describes the known failure mechanisms that have been characterized in MEMS technology. While the bulk of the chapter is dedicated to mechanical fracture, it must be understood that each failure mechanism will have a different level of predominance on different devices. Chapter 4 describes the basic material properties of common MEMS materials and relates these to the theory presented in Chapter 3.

Chapter 5 provides a description of common MEMS processing techniques. Both the discrete steps used to make the devices and the combination of those steps into a coherent process are discussed. A description of common MEMS device elements is presented in Chapter 6, along with relevant reliability concerns.

Chapter 7 discusses methods for modeling structure using finite element analysis. Chapter 8 involves reliability issues in packaging. Chapter 9 describes common test structures used to characterize the materials properties and structures discussed in Chapters 3 and 6.

Finally Chapter 10 offers a summary of the ways to use the information from the previous chapters to develop a reliable, space qualified, MEMS device. The information in this document is only a compilation of much deeper works and it is felt that users of this guideline should reference other documents listed throughout this guideline in the process of furthering MEMS reliability.

I would also like to thank the people involved in the production of this document. Sammy Kayali provided both technical advice and moral support throughout the arduous process of writing this guideline. Joseph Bernstein helped in the organization of the guideline and helped me to understand the material in Chapter 2. Bill Tang of the Micro Devices Laboratory at JPL gave great help in the processing area and lent his general expertise to improving the quality of the guideline. Dave Gerke, the resident packaging expert at JPL, was instrumental in producing the material on packaging issues in MEMS. Jim Newell and Kin Man in the Engineering Technology section at JPL provided invaluable modeling and dynamic testing material for the guideline. Finally, Thomas Kenny proofread the document and provided valuable feedback in the editing phase.

I would also like to acknowledge those people that did not contribute to the document itself, but who helped to make it possible through their encouragement. Russell Lawton, as the PI for MEMS Reliability at JPL, procured the funding for this document and acquired many of the images contained herein. Noel MacDonald, an electrical engineering professor at Cornell, provided the academic encouragement to enter into this emerging field and, without his teaching, this document would never have been produced. Norman Tien, also an electrical engineering professor at Cornell, helped by explaining some complicated issues in the field of surface micromachining. Rishi Khanna, Valdis Rigdon, and Dipak Srinivasan, also of Cornell, provided the incentive to start writing this document back in December of 1996. Greg Radighieri of Texas A&M also helped through his input and valuable insight into mechanical engineering issues.

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Abstract

This guide is a reference for understanding the various aspects of microelectromechanical systems, or MEMS, with an emphasis on device reliability. Material properties, failure mechanisms, processing techniques, device structures, and packaging techniques common to MEMS are addressed in detail. Design and qualification methodologies provide the reader with the means to develop suitable qualification plans for the insertion of MEMS into the space environment.

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