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Book Reviews

Thermal Stress and Strain in Microelectronics Packaging. Edited by John H. Lau, Van Nostrand Reinhold Publishers, New York, 1993, $89.95

REVIEWED BY PETER A. ENGEL[1]

The most prevalent forms of loading in microelectronics packaging equipment derive from a multitude of thermal effects, evident from manufacturing to cyclic operation. This book undertakes the formidable task of describing the relevance of temperature to the state of stress and strain in all the common packaging structures; its influence on materials and interconnections, modeling and experimental methods used, reliability aspects, etc. By enlisting as chapter authors many of the seasoned veterans of research and development of the field, the book succeeds in being a veritable storehouse of up-to-date information.

In the first chapter Lau states the fundamental equations of thermoelasticity, and outlines plasticity, viscoelasticity, creep and hyperelasticity, with applications to electronics packaging (EP) problems. The expansivity (CTE) of multilayer structures is treated by Hall, followed by Yin's analytical methods for anisotropic layers, and a study of transient thermal stresses by Kuo and Chen. The temperature dependence of the CTE of many materials used in EP is then discussed.

A chapter on thermal stress considerations in die-attachment is followed by die measurement using piezoresistive stress sensors. Voloshin next expounds on enhanced moire interferometry. Its power is underlined by the following discussion on the correlation of analytical (composite mechanics) and experimental approaches to thermally induced board warpage. Thermal stress induced open-circuit failure in thin film metallizations is handled by the Northwestern Univ. team, and stress-induced voiding in passivated narrow line metallizations on ceramic substrates, by Cornell's.

For plastic packages, the predicted bow is modeled by Suhir. A chapter on thermal- and moisture stress analysis follows, and in the next one, moisture resistance degradation during solder reflow is discussed.

Some of EP's outstanding problems, the thermomechanical fatigue and fatigue life of solder joints are treated by two chapters. Microstructural evaluation under thermal cycling and aging is then followed by the treatment of solder joint reliability of leadless chip carriers, with explicit work on power cycling. Solder creep-fatigue interactions with compliant leaded surface mount components are described in the framework of solder constitutive laws, and the role of lead stiffness.

Thermal stress issues in plated-thru-holes is discussed by Barker and Dasgupta. Lau et al. follow with the analysis of ceramic pin grid arrays soldered to orthotropic epoxy substrates. Discussing the mechanics of wire bond interconnects, Pecht and Lall describe numerous bond tests. A chapter on the corrosion in microelectronics packages (responsible for 20% of failures!) includes the use of corrosion reaction equations, and modeling the time-to-failure.

These 23 chapters are well aligned to assure a good continuous flow of the subject matter. I highly recommend this book for the library of anyone engaged in EP stress and strain analysis.

Structural Analysis of Printed Circuit Board Systems by Peter A. Engel, Springer-Verlag, New York, 1993, p. xix–291, $79.00.

REVIEWED BY J. H. LAU[1]

Structural Analysis of Printed Circuit Board Systems is written by a professor with more than 20 years of industry experience. Based on the principles of theoretical and applied mechanics, Dr. Engel skillfully and systematically presents many important problems and useful solutions for the first level packages, e.g., chip carriers, second level packages, e.g., printed circuit cards, third and fourth level packages, e.g., monther boards and framed structures.

The first two chapters deal with the classical theory and experimental methods of mechanics and the basic concepts of finite element methods. Chapter 3 presents the physical and mechanical properties of the key components for the first, second, third, and fourth level packages and their testing methods. These three chapters are not lengthy, however, the important features of mechanics and information for later analytical treatments of this book are given.

Chapter 4 through 14 summarize some of the important results in structural analysis of printed circuit board systems. In Chapter 4, the solder constitutive equations and forces of a leadless ceramic chip carrier are thoroughly discussed.

One of Engel's basic contributions to mechanical analysis was the application of elastic foundation modulus for a solder pin. Through this elastic foundation theory, the forces and moments in the pin, solder, and interface of a pin grid array system are determined (Chapters 5 and 6).

Another of Engel's basic contributions to mechanical analysis was the application of "local assemblies," "building blocks," and Engel-Ling theory to the compliant leaded surface mount systems. Through these treatments, the lead forces

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in a single-sided/double-sided/stacked/hybrid surface mount assembly subjected to mechanical/thermal/fatigue conditions can be determined (Chapters 7 through 11).

The dynamic analysis of printed circuit board systems is presented in Chapter 12. It shows that the module-populated systems can be represented by "smearing" or "lumping" techniques. This is welcome news for structural analysts, since these methods not only save computing efforts but also capture the important features of a complex system. Chapter 13 presents some plated through holes results. Both global (module-to-card) and local (board and copper barrel) effects are discussed.

The closing chapter presents a case study of the IBM 9370 card enclosure system. Static and dynamic structural analyses of the frame, planar boards, ZIF electrical connectors, and cards are skillfully presented.

Overall, the book is pulling together a lot of qualitative and quantitative information of printed circuit board systems. It is an important contribution to the field and is a useful reference book for engineers and students working in this area. I recommend it to anyone who is interested in finding stresses and strains in their electronic packaging and interconnect systems by structural analysis.