

Implementing Lead-Free Electronics

- ✓ Lead-free manufacturing know-how
- ✓ Real world lead-free production examples and options
- ✓ Making a smooth transition to lead-free production

Jennie S. Hwang, Ph.D.

LEAD-FREE IMPLEMENTATION AND PRODUCTION

A Manufacturing Guide

JENNIE S. HWANG

McGraw-Hill

New York Chicago San Francisco
Lisbon London Madrid Mexico City Milan
New Delhi San Juan Seoul Singapore
Sydney Toronto

Library of Congress Cataloging-in-Publication Data

Hwang, Jennie S.

Implementing lead-free electronics : a manufacturing guide / Jennie S. Hwang.
p. cm.

Includes bibliographical references.

ISBN 0-07-144374-6

1. Lead-free electronics manufacturing processes. 2. Environmental protection. 3. Electronic industries—Environmental aspects. I. Title.

TK7836.H93 2004

621.381'028'6—dc22

2004059234

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2 3 4 5 6 7 8 9 0 DOC/DOC 0 1 0 9 8 7 6 5

ISBN 0-07-144374-6

The sponsoring editor for this book was Stephen S. Chapman and the production supervisor was Pamela Pelton. It was set in Fairfield by J. K. Eckert & Company, Inc.

Printed and bound by RR Donnelley.

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To all who have courageously contributed to the initiation of the lead-free electronics.

To all who have diligently conducted sustained research in lead-free technology.

To all who have pioneered the implementation of lead-free electronics production.

To all who have disseminated broad-based information of lead-free product options.

To all who have disseminated broad-based information of lead-free process options.

To all who have truly advanced the electronic solder technology over the last three decades.

PREFACE

In the electronics industry, market demand, global competitiveness and the ever-shortening life cycle of electronic gadgets have been driving technological development. Environment-friendly manufacturing and the delivery of environmentally benign end-use products that are safer at the end of product life cycle have become essential to technology-business competitiveness. This is a continuing challenge to the industry.

The overall goal of this book is to help the industry meet and exceed the challenge of designing future electronics with both performance and environment in mind, meanwhile achieving manufacturing agility and efficiency for producing both today's and future products.

This book is a “companion” to the author's last book on the general subject of lead-free technology. The last book* covered lead-free technology from the perspective of preparing for implementation and production. This book focuses on the actual implementation and production of lead-free packages and assemblies. These two books are designed to be complementary.

It is the author's belief that a broad-based information flow across the continents would benefit all. The desire to facilitate this information flow and to enhance the knowledge base prompted the writing of this book. It is also the author's belief that effective implementation and a sound manufacturing system stem from an understanding of broad-based information and a familiarity with available options. With this knowledge base, we can achieve the ability to manufacture electronic products that are globally competitive in performance, reliability, and cost.

The book is laid out as a quick guide, providing successful examples in the global landscape in conjunction with basic principles related to the implementation and production of lead-free electronics.

**Environment-Friendly Electronics—Lead Free Technology* (ISBN: 0-901-150-401), Electrochemical Publications, Great Britain, 2001.

This book, comprising ten chapters, covers ten major topics corresponding to the thought processes and operational flow on the production floor. The book is written in an easy-to-read format, describing relevant “cases” that illustrate established, successful operations that have been converted to lead-free systems. The numerous illustrations are intended to reflect viable conditions and scenarios so that manufacturing mishaps can be avoided or minimized.

The author has been privileged to work with surface mount technology (SMT) manufacturing since its inception. During SMT’s dynamic, 25-year evolution, the author has engaged in manifold functions in managerial and leadership positions as well as hands-on situations, ranging from developing solder paste technology and formulae, to improving SMT production yield and defects, and to solving field failure and reliability issues in both technology and business arenas, in commercial and military sectors.

The most valuable part of the journey has been the opportunity to visit the SMT production facilities of most of the world’s major original equipment manufacturers (OEMs) and electronic manufacturing services (EMSs) and to have provided hands-on solutions to challenging problems and issues. Through the initiation of the U.S. Department of Defense Mantech program and as an invited advisor, for the past 15 years, the author and her team have performed sustained and systematic research work on lead-free development. And for the past six years, the effort has focused on implementing lead-free manufacturing on the production floor. While delivering lectures during this period, the author has cherished to share and exchange information with more than 15,000 managers, engineers, and researchers in the industry around the world. The author thanks those who have participated in the dialog also thanks the organizations and individuals who have organized and sponsored so many lectures and speeches in a timely fashion to facilitate the dissemination of this information.

It is hoped that the book shares an integrated knowledge of the author’s 15-year lead-free development and production

endeavor and her 25-year real-world SMT production experience.

Given the book's focus on implementation and manufacturing know-how, it is formulated on the assumption that readers have acquired the requisite basic knowledge in preparation for the implementation process. Nonetheless, for the readers' convenience, Chap. 1 highlights key points in relevant areas within the scope of the technology of, and preparation for, lead-free implementation. The other nine chapters are designed to follow a logical sequence in line with the production flow. Accordingly, Chapter 2 discusses *manufacturing implementation approaches*, and Chap. 3 covers the *selection of lead-free alloys for solder interconnections*. The subjects of *applying solder paste* and *selecting component coatings and PCB surface finishes* are discussed in Chaps. 4 and 5, respectively. With respect to soldering, *applying mass reflow soldering*, and *wave soldering and selective soldering* are treated separately in Chaps. 6 and 7. Among the most frequently asked issues and concerns are *compatibility* and *cost*, and these are illustrated in Chap. 8.

As the industry is continuously working to reduce defect rates and minimize rework and repair, Chap. 9 delineates specific concerns and commonly occurring production defects related converting to lead-free. The chapter focuses on the issues that have occurred, are most likely to occur, or are prone to being magnified. The chapter also covers the corresponding preventive or remedial steps by identifying the causes of defects and formulating solutions. The book concludes with Chap. 10, on *reliability* and *accelerated temperature cycling tests*, then provides summary remarks.

It is hoped that the integrated treatment of information, with embellishment using illustrative case studies, will be of value to many in approaching the manufacture of lead-free electronic packages and assemblies. It is also hoped that the text will stimulate further innovations and developments in producing nearly defect-free products.

As always, the author wishes to acknowledge her debt of gratitude to the considerable number of people (the complete enumeration of whom would not be practical here), who have

contributed directly or indirectly to the knowledge, insights, and inspiration that have enhanced the author's career and nurtured her as a person. Special mention is given to Mr. Charles A. Harper for his long-standing contributions to the industry and his tireless effort in making the *Electronic Packaging and Interconnection Series* possible. Special thanks should also be given to the publisher's staff for their support and effort, particularly Mr. Steve Chapman and Mr. Jeff Eckert. The author gratefully acknowledges her indebtedness to many colleagues and business associates for their support and encouragement. Finally, the author gives deepest gratitude to her family—Leo, Raymond, and Rosalind—for their endless understanding, caring, and love.

Jennie S. Hwang, Ph.D.

August 2004

Cleveland, Ohio, U.S.A.

FOREWORD

The field of electronic packaging and materials, always important in electrical and electronic systems, has become one of the most dynamic areas in modern electronics. Indeed, one could say that electronic packaging and materials have become the critical limiting factors in the success of modern electronic systems. While this is true across the broad spectrum of materials and electronic packages, in no area is it more true than in the area of solders and soldering. After having overcome the multitude of problems associated with bulk, paste, and deposited solders for ever increasing component densities with ever decreasing component size and interconnection spacings, the problems of lead-free environments came to the forefront. Understandably, solders, with their high lead content, became the area of prime attention in the electronics industry. And with governments and health agencies clamoring for lead-free electronics, the issue of lead-free solders arose front and center. Fortunately, the industry has strongly responded to the need for lead-free solders.

While many have contributed to the necessary advances in lead-free solder technology, none has had a larger role and greater impact than Dr. Jennie Hwang, the author of this new book. She is both widely known and highly respected internationally for her efforts and achievements. It has been my pleasure to be associated with her in this important period of advances in this field.

This new book might be said to be the culmination of all of these efforts, since it clearly and thoroughly presents an integrated base of knowledge, from development to production. The focus of the book on implementation and manufacturing know-how will make it invaluable as the electronics industry increasingly changes from the use of lead-based to lead-free solders. With the breadth, thoroughness, and clarity of this book, it is highly likely to become the bible for implementing lead-free solders into the broad electrical and electronics industries.

Coming from a veteran of the electronic packaging and materials fields, this new book is absolutely an impressive, unparalleled textbook that contributes to critical manufacturing technology in the electronics/microelectronics industry, providing real-world value—a must for all involved in research, manufacturing, and decision-making management.

Charles A. Harper, Editor-in-Chief
Electronic Packaging and Interconnection Handbook
Electronic Packaging and Interconnection Series

ACKNOWLEDGMENTS

My grateful thanks are tendered to the following companies and individuals who have provided photographs, test results, information, and/or advice:

AkroMetrix LLC	Nihon Superior Co., Ltd.
Mr. Alan Barney	Mr. Keith Sweatman
Mr. Charles M. Harper	Singapore Asahi Chemical &
Mr. Patrick Hassell	Solder Industries PTE,
DEK	Ltd.
Dr. Dionysios Manassis	Mr. Tetsuro Nishimura
Edward Ibe	Dr. Dirk A. Zwemer
Mr. Karl Loh	Mr. Tom Baggio
Zymet, Inc.	Dr. Ken Suetsugu
Dr. Yun Zhang	Panasonic–Matsushita
Cookson Electronics—	Dr. Roger Clough
Enthone Inc.	National Institute of
Mr. Mark Whitmore	Standards and Technology
Microperipheric Technology	Mr. George Lucey
Center, Technical	U.S. Army Research
University Berlin	Texas Instruments
Mr. Bob Willis	Doug Romm
WWW.leadfreesoldering.com	Donald Abbott

And collective thanks to all those individuals and publications cited in the references of each chapter.

ABOUT THE AUTHOR



Dr. Jennie Hwang's wide-ranging career encompasses entrepreneurship, corporate executive, innovative research, worldwide manufacturing and technology services, corporate governance, as well as leadership positions within professional organizations. She has contributed in technological, business, and academic arenas. Her work is highlighted by numerous national and international awards and honors, including her alma mater's Distinguished Alumni Award.

Among her many awards and honors are citations by the U.S. Congress and the Ohio Senate and House for her outstanding achievements; membership in the National Academy of Engineering; induction into the Women in Technology International Hall of Fame; being named a "Star to Watch" by *Industry Week* magazine; and induction into the Ohio Women's Hall of Fame. She has worked in various "woman pioneering" capacities. She received a YWCA Women of Achievement Award, for which her citation read,

Being honored as the *first woman* is a way of life for Dr. Hwang..., including being the first woman to receive a Ph.D. from Case Western Reserve University in Materials Science and Engineering....

Dr. Hwang has extensive hands-on experiences in technology transfer and bringing innovations to the stage of commercialization. She has been a pioneer and major contributor to electronic surface mount technology since its inception. She is also a highly solicited advisor to industry, government, and universities.

Hwang is the inventor of a number of patents and the author of more than 250 publications, including being the sole

author of several internationally adopted textbooks and the co-author of several other books. As a columnist for *SMT* magazine, a globally circulated trade journal, she monthly addresses technological issues and market thrusts; her views are widely solicited and highly regarded worldwide.

A popular keynoter and featured speaker at national and international events, she shares her thoughts and vision with various institutions. Her speaking engagements range from commencement keynote speeches at universities to discussions of emerging technologies at the U.S. Patent and Trademark Office (USPTO). Over the years, she has shared her knowledge and experience by delivering professional advancement lectures to more than 15,000 professionals and researchers. In addition, she is a prolific author and speaker on education, the work force, and trade, social, and business issues. Titles of her various addresses include "Leadership," "Innovation," "Entrepreneurship," "Preparation for the New Millennium—Education, Technology, and Workforce," "Education in Science and Engineering," "Modern Manufacturing Workforce," "Asia's Road to Economic Recovery," "Accelerated Tax Depreciation for High-tech Manufacturing," "Virtual Corporation," "Modern Woman," "Women in Education, Technology, and Workforce," "Affirmative Action," "International Trade and Trade Promotion Authority," "Changes and Coping with Changes," "Welcoming the Digital Economy," "Technology, Education, Trade, Jobs," and others.

As a member of many professional organizations, she has served in various capacities, including the National President of the Surface Mount Technology Association, board trustee of ASM International, and a member of the National Research Council/National Materials Board's Globalization Committee.

Her educational background includes a Ph.D. in Engineering from Case Western Reserve University, plus two M.S. degrees in Chemistry and Liquid Crystal Science from Columbia University and Kent State University, respectively. She also has a bachelor's degree in Chemistry and is a member of the U.S. Commerce Department's Export Council.

Dr. Hwang has held various senior executive positions with Lockheed Martin Corporation, Sherwin Williams Company, SCM Corporation, and International Electronic Materials Corporation. Currently, Hwang is the principal of H-Technologies Group, Inc., an intellectual property and service company providing business and technological solutions to the electronics industry. In addition, she is a Distinguished Adjunct Professor at the Engineering School of Case Western Reserve University, and she serves on the university's Board of Trustees. She also serves on the board of several NYSE Fortune 500 companies and various civic boards.

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