Lead-Free Soldering

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Preface

The past few years have seen major developments in soldering materials and processes for electronics assembly manufacture due to the movement from tin-lead to lead-free soldering. The removal of lead from electronics solders due to environmental considerations first developed with proposed US legislation in the early 1990s. At that time, the alternatives had not been fully explored, so a ban on the use of lead in electronic solders was put on hold. However the seed was sown for development with various projects initiated during the 1990s in Europe, the Americas, and Asia.

Based on government pressures, Japan OEMs began to move to lead-free solder products from 1998 and this, combined with the European Union ROHS (Restriction of Hazardous Substances) legislation enacted in 2006, drove the global manufacture of electronics consumer products with lead-free solders. From 1998 to the present, the development of lead-free solder materials and processes has progressed to such an extent that development work moving forward will typically only concentrate on lead-free solders and components rather than tin-lead solders and components.

This book aims to give the latest information on development of the lead-free soldering materials and processes and identify where more work is needed. The chapters of the book describe legislation, alloys, reflow, wave, rework, reliability, backward and forward process compatibility, PCB surface finishes and PCB laminates, and standards affecting the general lead-free soldering arena.

The information in the book is provided by many authors who are fully immersed in the transition from tin-lead to lead-free soldering as part of their daily work lives. It is our hope that this book provides a useful source of knowledge and information for process engineers and other functions and stimulates further work in this area.

The chapter authors are to be thanked for spending their time and effort to create their respective chapters, which is difficult to do when combined with a busy work and personal family schedule.

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For my Mum (Kuldip Kaur Bath), Dad (Harbans Singh Bath), wife (Piyanoot) and three little girls (Palm, Mint and Surinder)

Introduction

The discussion to create this book on lead-free soldering came in October 2005 during a U.S. National Electronics Conference organized by SUNY-Binghamton. There appeared to be a need for a lead-free soldering book which covered subjects in detail but not to a depth which would not be practical for the process engineer. This book brings together a diverse array of persons from different companies and expertise who are currently in the area of lead-free soldering development. The contents of the book provide a guide to understanding the main issues in lead-free soldering.

Lead-free and other environmental regulatory legislation is appearing rapidly and affecting the electronics industry. Engineers need to be aware of what will affect them currently and what is potentially on the horizon to help them to adjust and adapt. The first chapter (by Canyon Snow Consulting LLC) covers a review of existing and upcoming lead and other material restriction legislation and discusses the driving forces behind them.

Although there have been many book chapters and paper discussions of lead-free alloys, there is a need for persons (from Purdue University and NIST (National Institute of Science and Technology)) who have been involved in the forefront of lead-free alloy development to review various properties of lead-free solder alloys, in particular those alloys which are being predominantly used in the industry. This book provides an in-depth review of them and a discussion of the issues surrounding them in Chapter 2.

The main use of these alloys is in surface mount assembly, and Chapter 3 reviews SMT lead-free reflow soldering which focuses on the main lead-free alloy of choice: tin-silver-copper (SnAgCu). An area where there is a minimal amount of research papers and virtually no book chapters available is lead-free wave soldering as the focus of lead-free research development has centered on surface mount assembly. A chapter on lead-free wave soldering was identified as a gap which would be of use to the process engineer (Chapter 4). Even though rework is not desired, and should be minimized, it is part of the manufacturing process. There is a minimal amount of research papers and virtually no book chapters available on lead-free rework and this was also identified as a gap to be of use to the process engineer (Chapter 5). All three of these chapters were written by authors from an electronics manufacturer (Solectron Corporation).

After the board is assembled, the main question which is asked is 'will the assembled solder joint be reliable?'. Chapter 6 concentrates on one aspect of reliability from an author (from EPSI Inc.) who has been at the forefront of lead-free reliability investigations. This chapter begins with a summary of trends in reliability test results for some of the mainstream lead-free alloys used in board assemblies. It then presents a case study with the goal of presenting the type of data, material properties and analysis that are needed to estimate component attachment reliability for a given soldering alloy under thermal cycling conditions. One objective of this exercise is to illustrate the level of details that are required to develop stress/strain analysis models and estimate component attachment reliability in lead-free board assemblies. By definition, reliability is product and application specific and blanket statements about the reliability of a lead-free assembly need to be considered with caution. Part of the solder joint assembly reliability discussions also focuses on the transition to lead-free soldering where a lead-free solder paste or wave alloy may be assembled with tin-lead components, and a tin-lead solder paste or wave alloy may be assembled with lead-free components. Although there have been some papers discussing whether there are any reliability issues with this 'mixed' assembly processing, there have been few or no book chapters reviewing this specific area. The author of this chapter (from Cal Poly State University) gives an objective and detailed discussion of the issues with possible solutions. Chapter 7 also discusses the use of lead-free press-fit components from an electronics assembler (Solectron Corporation) with first hand experience of some of the potential issues that can be faced.

One area which is a work in progress is the development of PCB laminate materials for lead-free soldering, particularly laminates for thicker high end reliability boards. The chapter author (from SUN Microsystems) gives an objective and focused review of PCB laminates for lead-free soldering with testing methodologies and a discussion of the need and reasons for higher temperature-rated laminates for lead-free soldering (Chapter 8). There have been many papers written about lead-free board finishes but there have been few book chapters which give an objective and detailed discussion of the different lead-free board surface finishes available. The authors, who are part of a chemical plating supplier company (Atotech Inc.), provide a clear discussion of the subject which will be a good reference guide for process engineers (Chapter 9). The various advantages and disadvantages of the different lead-free board surface finishes are discussed.

No book on lead-free soldering should typically be finished without a review of existing and developing lead-free standards identifying where there are gaps in development. Chapter 10 is not a complete list of existing

and developing standards, but of those which have or will likely have a role to play as reference standards for process engineers and is written by an electronics assembly manufacturer (Solectron Corporation).

Although each chapter has its own conclusion, a small conclusions section at the end of this book covers a discussion of the main conclusions from each chapter, with a discussion of some of the areas which will need to be explored and developed in the future. It is our hope that this book will provide a good grounding of the general areas for lead-free soldering for process engineers and other functions and stimulate discussion and development in this area.