

Preface

The wonders of modern technologies may seem to be achieved by the development of exotic materials such as Si and GaN single crystals, graphene, and nano-materials. However, what is not well known is the fact that those wonders exist simply because of seemingly benign-looking small piece of a metallic alloy known as solder. Without them effectively and cheaply carrying power and signals from one device to the other, all the technological advancements essential for modern and future life are likely to disappear. It must be a surprising experience to anyone to realize that what we enjoy is possible because of cheap Sn-rich solder. In essence, solder joints or solder interconnects connect the world and therefore are infrastructure essential for our daily life.

Tin itself, a long friend to human civilization as it enabled the Bronze Age (in a supporting but invisible though extremely important role), may have a higher ambition since it was shaped into a sphere-shaped solder ball that is connecting the world together. Maybe it saw over the years its friends, Si, a near neighbor just upstairs, and fellow metals Cu and Fe, become dominant players in bringing our civilized structure into the global village we live in together and decided to leave behind a supporting role to become one of the bigger elements.

This book is about lead-free solder technology based strongly on microstructure evolution and reliability in application perspective, but during the preparation of the book, the authors saw a more fundamental story, reflecting many aspects of the world of materials. Since the property and function of the interconnect is a combination of microstructure and chemical composition, it is surrounded by all possible phenomena that we can see in various metallic materials.

We will see the interaction between several interfaces and layers. The properties of these individual but connected layers have interesting relationships since if you strengthen just one layer, the failure layer just shifts to a different weaker link. So understanding the interconnect is to begin with individual layer and expanding the understanding to the whole system. Without understanding the whole system, it is hard to come up with a valuable assessment or reliability and further along to find a solution for a better and stable interconnect.

This book is the tip of the iceberg from the point of view of making the performance of solder joints and, thus, the performance of electronic systems predictable, as most designs are made so that the joint fails before other components do. Predictable performance of an electronic system depends on predictable performance of tin in solder joints. Making this prediction is challenging because tin has rather unusual properties for a metal, as it is very anisotropic. To make its performance predictable, effective material models are needed. To make a useful model, the mechanisms of deformation and damage nucleation and growth must be understood, and these mechanisms are becoming more and more clearly understood in the past few years.

One of the major challenges in the current decade is to predict microstructure evolution and hence property evolution from the beginning to end of life of an electronic product. When this becomes possible, design for reliability can be realized. In contrast to fluids, this challenge is especially large for solid materials, because the deformation and thermal history lead to irreversible changes in microstructural features that affect how the next incremental change occurs. Hence there is a history/memory effect that requires knowledge of all that has happened prior to a given point in time and space, all the way back to the point of formation of the crystal. This is in contrast to fluids where there is no long-term memory of past conditions, and only the most recent history is needed to predict the next incremental change.

So we will begin with the single bulk solder material, then consider what differs in solder joints, then interconnects, and then the thermal, mechanical, and chemical performances followed by future challenges in next-generation electronic devices.

We hope that our growing appreciation for the complexity of Sn and solders and, in particular, its ways of adapting to a continuously changing environment can support you in your efforts to improve the reliability and performance of the electronic systems that our modern culture depends on.

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From Microstructures to Reliability

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