Reliability issue of solder joints in microelectronics due to evolution of microstructure

Citation for published version (APA):
Matin, M. A., Vellinga, W. P., & Geers, M. G. D. (2001). *Reliability issue of solder joints in microelectronics due to evolution of microstructure*. Poster session presented at Mate Poster Award 2001 : 6th Annual Poster Contest.

Document status and date:
Published: 01/01/2001

Document Version:
Publisher's PDF, also known as Version of Record (includes final page, issue and volume numbers)

Please check the document version of this publication:

• A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
• The final author version and the galley proof are versions of the publication after peer review.
• The final published version features the final layout of the paper including the volume, issue and page numbers.

Link to publication

General rights
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license above, please follow below link for the End User Agreement:

www.tue.nl/taverne

Take down policy
If you believe that this document breaches copyright please contact us at:

openaccess@tue.nl

providing details and we will investigate your claim.

Download date: 16. Nov. 2023

technische universiteit eindhoven

Reliability issue of solder joints in microelectronics due to evolution of microstructure

M.A.Matin, W.P. Vellinga, M.G.D.Geers
Eindhoven University of Technology
Faculty of Mechanical Engineering
Phone: +31-40-247-2849, E-mail: m.a.matin@tue.nl

Introduction

With the advent of surface mount technology (SMT), solder materials are used to meet the dual purposes of mechanical and electrical interconnections. During service, the solder joints are subjected to fluctuating thermal stresses resulting from a combination of thermal excursions experienced by the package and differential thermal expansions (CTEs) between the materials caused either by power cycling or environmental temperature changes. The peak temperature of the solders while thermal cycling rises to $> 0.5\,T_m$, where T_m is the melting temperature of the solder in Kelvin. At these temperatures, atomic migration of various species takes place resulting evolution of microstructure [1] and eventually cause concomitant premature failure of the solder joints. The designing of reliable solder joints especially with the new sets of lead free solder alloys keeping consideration of thermo-mechanical failure is a big challenge to the microelectronics industry. Therefore, determination of microstructural evolution of the solder joints under various loading conditions is indispensable.

The evolution of microstructure under the influence of thermo-mechanical loading, however, is not yet characterized. Most of the studies, so far, have been performed on the evolution of microstructure under isothermal annealing condition which do not reflect the actual service condition. The present study will be focused on the microstructure evolution of lead free solders as well as eutectic Sn-37Pb solder by imposing a systematic thermal cycling and/or mechanical loading.

Methodology

The evolution of microstructure will be characterized under the following three circumstances:

- ☐ The application of thermal fluctuation within the temperature range of -50° to 125°C by using a thermal chamber.
- ☐ The influence of pure mechanical loading by the application of shear stress.
- ☐ The application of both thermal and mechanical loadings.

Construction of the deformation mechanisms map for lead free solder materials and simultaneous creep behavior study will be performed considering the following type of constitutive equation incorporating phase size (d):

$$\frac{\dot{\gamma}_p kT}{GbD} = A\left(\frac{b}{d}\right)^p \left(\frac{\tau}{G}\right)^n \tag{1}$$

where

$$D = D_0\, exp\left(\frac{-Q}{kT}\right) \tag{2}$$

Experimental studies

The evolved microstructure will be in-situ characterized by using optical microscope and the linear intercept method will be used to determine the various phase sizes. An X-ray microprobe analysis equipped with ESEM under proper calibration will be performed to determine the composition and type of the intermetallics. The average thickness of the intermetallic layer will also determined with the help of an Image Analyzer using micrographs. Finally, a correlation among the influence of various loads and their frequencies, evolution of microstructure, and reliability of solder joints will be figured out.

Conclusions

- ☐ Evolution of microstructure depends on: the composition of solders, under bump metallurgy (UMB), the cyclic temperature range and frequencies, imposed mechanical load.
- ☐ The classic eutectic microstructure possessing higher interfacial energy is not a desirable microstructure. To minimize the interfacial energy, eutectic colonies will grow and gradually become spheroid at the service temperature and deteriorate the properties [2].
- ☐ Intermetallic layer formed at the interface by the solder-substrate interactions has an indirect influence on the resultant ab initio microstructure of solder joints. The depletion of one component shifts the overall composition of the bulk solder (eutectic) to render off-eutectic and produces inhomogeneous microstructure.
- ☐ Intermetallic compounds occasionally exhibit a weakness in the solder joint and cause micro-strains due to the mismatch of CTE between the solder and intermetallic compounds. As the micro-strains exceed a critical value, micro-cracks may occur at the interface of solder/intermetallic compounds and might propagate, which would result in failure of the joint and hence influence the solder joint's reliability.

References:

[1] D.R. Frear. The mechanical behavior of interconnect materials for electronic packaging. *JOM*, 48:49–53, 1996.

[2] D. Tribula and J.W. Morris. *ASME JOurnal of electronic packaging*, 111:83, 1989.