Title	Visualization of EM process by FEM
Author(s)	Chun, Yu; Hao, Lu
Citation	Transactions of JWRI. 39(2) P.211-P.212
Issue Date	2010-12
Text Version	publisher
URL	http://hdl.handle.net/11094/12178
DOI	
rights	
Note	

Visualization of EM process by FEM†

YU Chun *, LU Hao *

KEY WORDS: (Electromigration) (Concentration) (Finite element method) (lead-free solder)

1. Introduction

Electromigration (EM) is a directional mass transporting phenomenon, which is induced by a high current density. It is a critical reliability issue in electronic packaging, since the dimension of the interconnects and solder bumps continuously decrease, and meantime, the current stressing increases. Up to date, there are a lot of reports on the investigation of EM mechanism in the flip chip solder joints from an experimental view [1,2]. A few works have also been performed to study the current density distribution in the solder bump by employing finite element modeling (FEM). However, the concentration distribution of the elements in the solder bump in the EM process is unclear.

This paper aims at investigating the concentration field in the solder joints under current stressing. And the model can be used to predict the EM lifetime of the solder joints.

2. Model

There is a well established function, which describes the relationship among the atomic flux and different physical field, it is,

$$\vec{J} = \vec{J}_{\mathrm{CH}} + \vec{J}_{\mathrm{EM}} + \vec{J}_{\mathrm{TH}} + \vec{J}_{\mathrm{ST}} = -\nabla(DC) + \frac{CD}{kT} eZ^{*}\vec{j} - \frac{CQ^{*}D}{kT^{2}}\nabla T + \frac{C\Omega\Omega}{kT}\nabla\sigma_{H} \qquad (1)$$

According to the second Fick's law, the concentration equation for a multi-field EM process is established,

$$\frac{\partial \mathrm{C}}{\partial \mathrm{t}} = \nabla \cdot [-\nabla(DC) + \frac{CD}{kT} eZ^{*}\vec{j} - \frac{CQ^{*}D}{kT^{2}}\nabla T + \frac{C\Omega\Omega}{kT}\nabla\sigma_{H} \qquad (2)$$

For simplification, $\vec{J}_{\mathrm{TH}}$, and $\vec{J}_{\mathrm{ST}}$ are neglected in this work. **Figure 1** shows the geometry model and mesh for a Cu/Sn-0.7Cu/Cu joint. 2.85A current was applied.

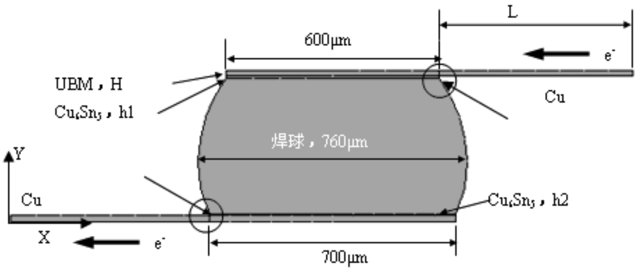
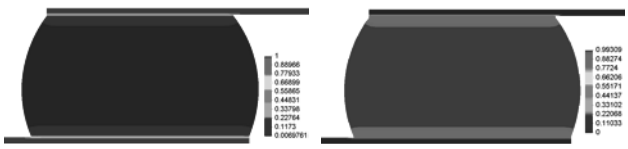


Fig. 1 Cross section of solder joint

3. Results and Discussions

Figure 2 shows the concentration fields of the Cu and Sn elements, just under the driving force from chemical potential. It is seen that the diffusion is uniform.



(a) (b)

Fig. 2 Diffusion under chemical potential. (a) Cu; (b)Sn

Figure 3 reflects the cross-sectional views of the current density distribution in the solder joints The current density distribution is non-uniform in the *XY* plane; most current concentrates on the entry and exit points inside the bump. The current crowding at the cathode side induces a maximum current density, which occurs at the entry point near the top Cu line.

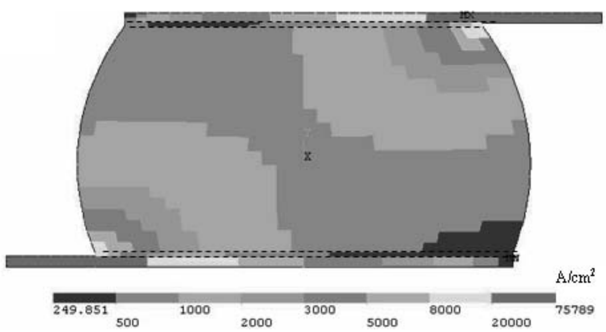


Fig. 3 Current density

† Received on 30 September 2010

* Materials Science and Engineering School, Shanghai Jiao Tong University, Shanghai, China

Transactions of JWRI is published by Joining and Welding Research Institute, Osaka University, Ibaraki, Osaka 567-0047, Japan

The maximum current density is the cause for the EM failure in the solder joints. The electron wind force generated by current crowding pushes the atoms from the cathode side to the anode side. So we can see the different concentration field, as shown in **Fig. 4**.

Fig.4 Diffusion of Cu under current stressing

Due to the higher concentration in the solder, the diffusion of Sn determines the formation of voids. **Figure 5** shows the concentration change of Sn under the electrical field. Basically, the Sn concentration change reflects two information, namely, where the EM-voids and where the crush happen, and the voids grow up with aging time. It is agreement with the Ref.[3].

Also, we found that the concentration change is different according to the distance away from the crowding zone, as shown in **Fig. 6** where near the crowding zone, the current stressing dominates the diffusion, and at the site far away from the crowding zone, where chemical potential determines the diffusion.

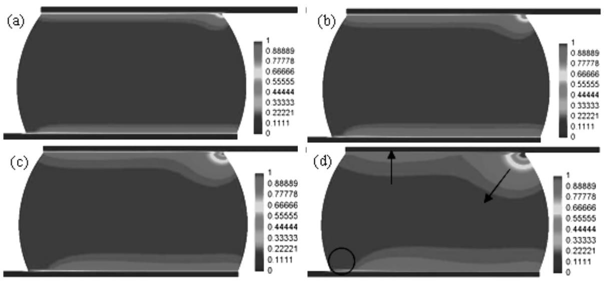


Fig. 5 Concentration change of Sn under electrical and temperature fields. 100, 300, 700, and 1000 hrs

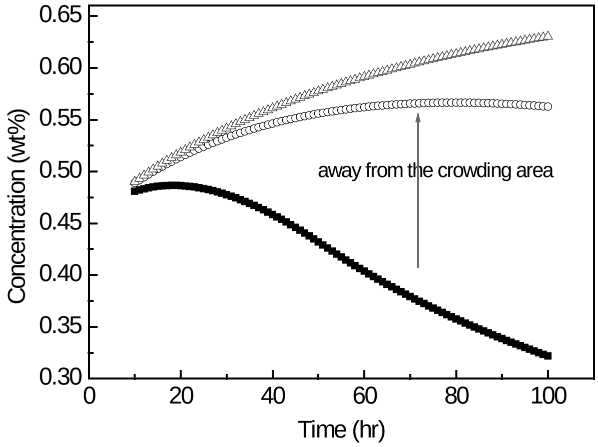


Fig. 6 Concentration change of Sn in cathode IMC

4. Conclusions

(1) A concentration equation was established to visualize the EM process;

(2) Atoms flow from the cathode crowding zone to the anode crowding zone under current stressing, which results in void formation at the cathode crowding zone.

(3) Atom diffusion is different according to the site from the crowding zone.

References

[1] K N Chiang, C C Lee, C C LEE: Applied Physics Letters, 88(2006), 072102.

[2] D Yang, Y C Chan, K N Tu: Applied Physics Letters, 93(2008) , 041907.

[3] T Y Lee, K N Tu, S M Kuo: Journal of Applied Physics, 89(2001), pp.3189-3194.