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Experiment Report Form

	Experiment title: Real-time 3D study of the structural modifications in solder joints due to current crowding	**Experiment number**: MA1113
Beamline:	**Date of experiment**: from: 15 Dec 2010 to: 20 Dec 2010	**Date of report**: 24.Aug.2011 *Received at ESRF:*
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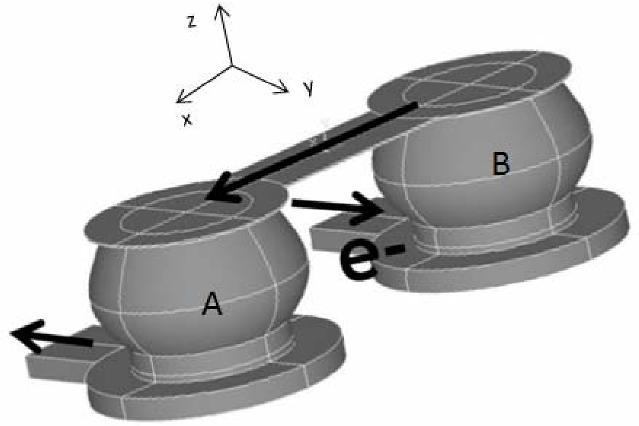
Report:

In the experiment MA1113, we in-situ characterized 3 types of flip chip Pb-free solder under two different electromigration testing conditions. The aim of the experiment is to study the void initial sites induced by electron flows and the void growth rate. Table 1 gives the summary of the sample we examined.

Type	UBM	Solder	Current Density	Temperature
1	Ti/Cu/Cu(7.5um)	SN100C	7.5MA/cm^2	130degC
			10MA/cm^2	
2	Ti/Cu/Cu(7.5um)	SAC1205	7.5MA/cm^2	130degC
			10MA/cm^2	
3	e-less Ni(5 um)/Au	SN100C	7.5MA/cm^2	130degC
			10MA/cm^2	

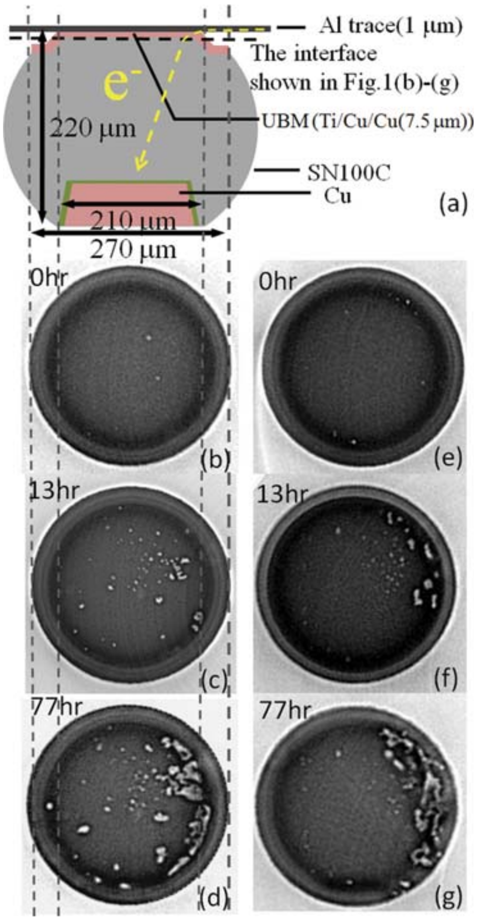
We powered six chips at the same time. Around every 24hrs, we took the samples out of the furnace and scanned them by white beam x-ray. Figure 1 shows the schematic diagram of the sample structure. There are two bumps on each sample, the electron flow comes from the bottom of Bump B and then goes through the Al trace on the top of these two solders, finally it goes out of the bottom of the Bump A. Therefore the upper right corner of Bump A is the entering point of the electron flow, which is so-called current crowding region. The current crowding region is believed to be the initial site of the void formation induced by electromigration. After the nucleation of the void, it will grow through the interface between solder and the UBM, as the direction of the electron current redistribution. Electromigration, basically, is a long-term diffusion phenomenon. Under a typical accelerating testing condition, hundreds of hour will be needed, or even more until the failure finally happens.

Figure 1



In our study, we monitored what happened inside testing solders from time to time and got the information of the electronmigration effect at early stages. Figure 2(a) A schematic diagram of the cross-section of the solder joint, showing the configuration and dimensions of the sample. Figure 2(b)-(d) show the cross-sectional slices reconstructed by SRCL of the sample I at the interface between the solder ball and UBM before, after 13 hr, and 77 hr of EM test, respectively, under a current density of 7.5×10^3 A/cm^2 at 125˚C. Figure 2(e)-(g) show cross-sectional slices of the sample II, before, after 13 hr, and 77 hr of EM test respectively under a current density of 1×10^4 A/cm^2 at 125˚C. Clearly, our results confirm the theory of electromigraion, indicating that the mainly voids was formed from the current crowding point. However, what is unexpected is there is not only one dominated void existing inside, but several small voids formed at the same time. This effect has never been founded by traditional SEM examination. The longest EM treatment is about 77 hours, when there is still no resistance change appeared. Actually the late stage of the real failure is also of interest. Since the beamtime is limited, we did not see it.

Figure 2



For comparison, Figure 3 shows the evolution of the interfaces of two unpowered solder bumps, which only suffered 130degC thermal aging. Compared to the image taken at 0hr, after 77hrs, there are also several small voids founded at the interface, which means the reaction between UBM and solder body can introduce vacancy saturation and thus void nucleation. This finding is new and worth a more deep study, however, it will not invalid the theory of electromigration, since in this case the distribution of voids is clearly random.

Figure 3

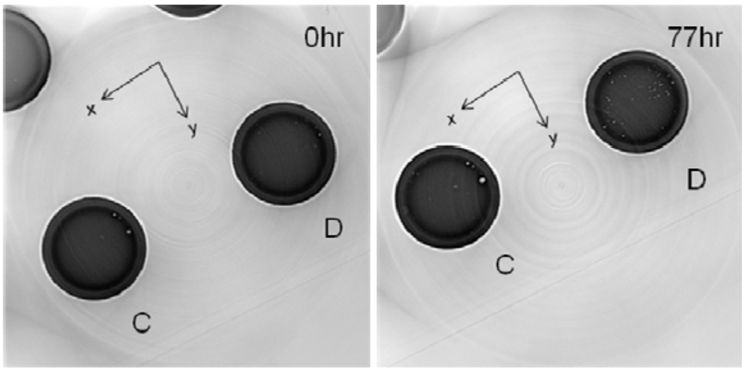
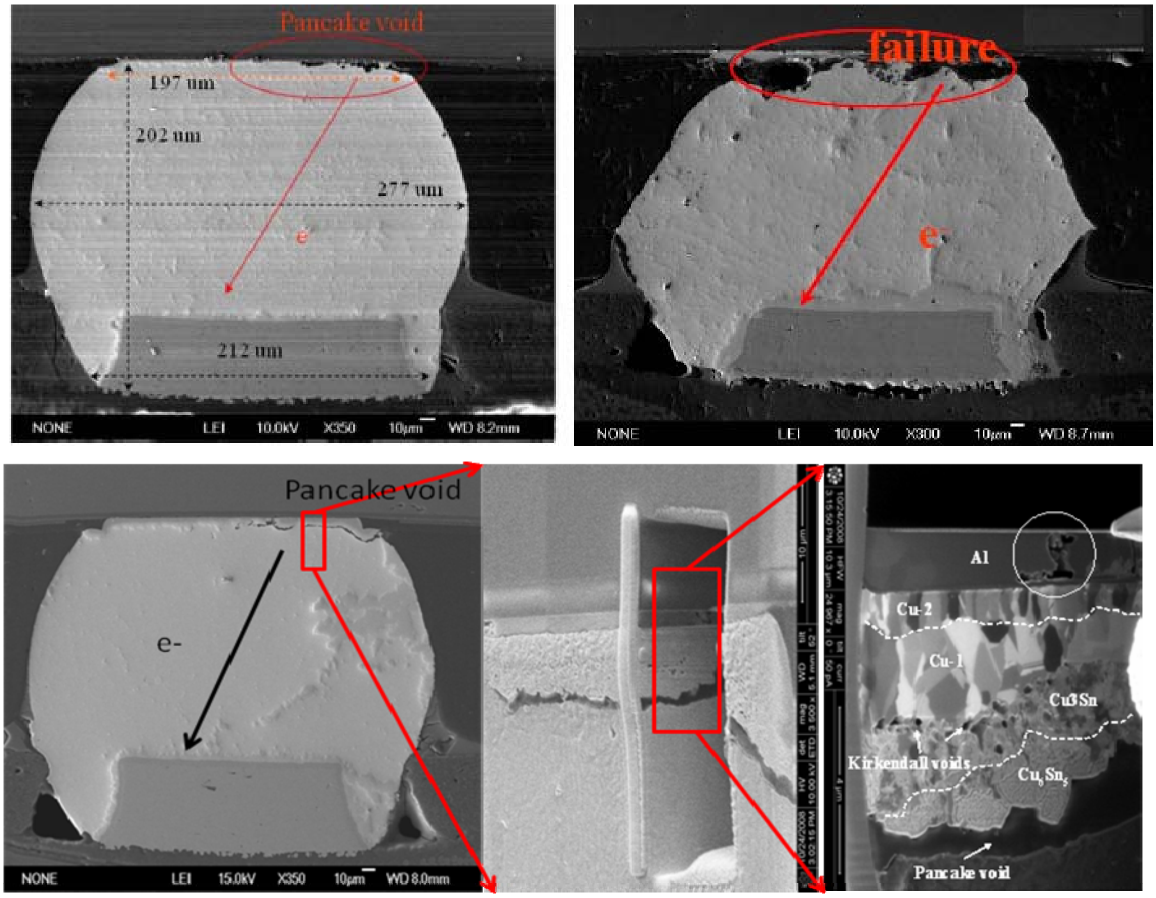


Figure 4 shows the SEM images of the cross-section of the same kind of solder bump. In the Figure, we can see the pancake void propagate through the upper interface from the entrance point of electron flows in one unfailed solder, and the other image shows a failed the solder at the later stage of eletronmigration. Additionally, the FIB images show the details of the pancake region. If we can have more beamtime, the later stage evolution of the solder bump until it fails is expected to see.

Figure 4



We have published part of the results in Applied Physcis Letters (**Abstract is attached in the end of this report).**

Tian Tian,Feng Xu, Jung Kyu Han, Daechul Choi, Yin Cheng, Lukas Helfen,Marco Di Michiel, Tilo Baumbach, and K. N. Tu. Rapid diagnosis of electromigration induced failure time of Pb-free flip chip solder joints by high resolution synchrotron radiation laminography. APPLIED PHYSICS LETTERS 99, 082114 (2011).

Another manuscript which uses optical flow to analyze the results is under preparation.

Abstract:

We performed a rapid diagnosis of electromigration induced void nucleation and growth in Pb-free flip chip solder joints. Quantitative measurements of the growth rate of voids during the stressing by 1.0_104 A/cm2 and 7.5_103 A/cm2 at 125 _C were conducted by synchrotron radiation high resolution x-ray laminography. The results were analyzed by the statistical model of Weibull distribution function [W. Weibull, ASME Trans. J. Appl. Mech. 18(3), 293 (1951)] of lifetime data. The Johnson-Mehl-Avrami phase transformation theory is proposed to provide a physical link to the statistical model and to estimate the lifetime of the joints at early stages.