The microstructural evolution of Sn-Pb solder

technische universiteit eindhoven

The microstructural evolution of Sn-Pb solder

M.A.Matin, W.P. Vellinga, M.G.D.Geers
Eindhoven University of Technology, Department of Mechanical Engineering

Introduction

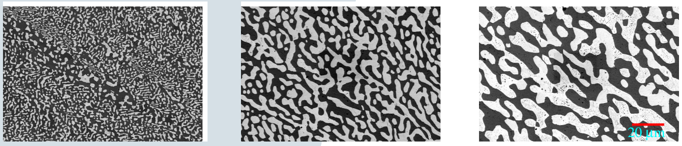
Eutectic Sn-Pb solder is one of the most commonly used joining materials which serves as mechanical and electrical connectors between printed circuit boards and components. The Sn-Pb solder is a 2-phase system, the microstructure of which evolves during its lifetime under thermo-mechanical (TM) loading condition. This evolved microstructure influences the mechanical properties of the solder. The mechanical response of solder to TM load dictates the lifetime and reliability limit of a circuit. It is therefore worthwhile to characterize quantitatively the evolution of microstructure of the solder in response to TM load.

Experimental techniques

As-cast and annealed specimens of liquid nitrogen (LN2) quenched eutectic Sn-Pb solder were characterized using Scanning Electron Microscopy (SEM). Micrographs were used to quantitatively determine the coarsening and the size distribution of α particles at two annealing temperatures, 373K and 423K and various durations of time. An image analysis technique was employed to measure area of the particles.

Results

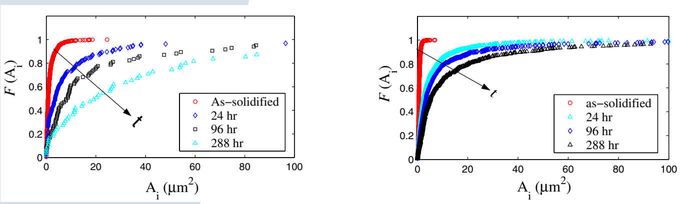
Shown in Fig.1 is the microstructure of isothermally annealed LN2 quenched solder specimens at various time at 423 K from a single area. The light and dark regions in the micrographs are α- and β-particles respectively.



(a) (b) (c)

Figure 1 *Microstructural evolution of LN2 quenched Sn-Pb solder at 423 K. (a) as-cast, (b) t= 24 hr, and (c) t=288 hr.*

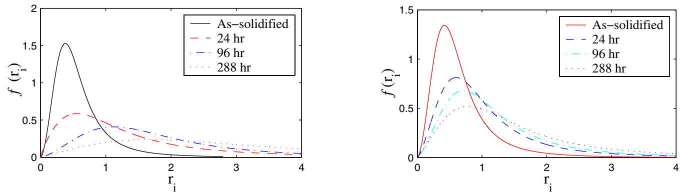
The normalized cumulative size distribution ($F(A_i)$) of α-particles of solder specimens at 423 K and 373 K are shown in Fig. 2. The figures show that the number of particles decreases and particles coarsen with increase in annealing time (t).



(a) (b)

Figure 2 *Normalized cumulative size distribution at (a) 423 K and (b) 373 K.*

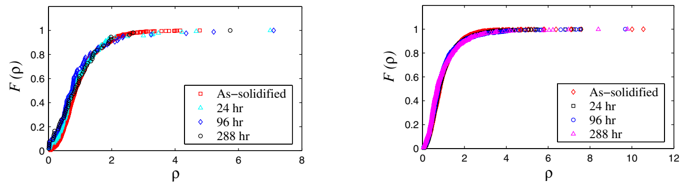
The probability density of α particles at 423 K and 373 K are shown in Fig.3. The figure shows that the maxima of each curve shifts towards higher radii indicating the gradual decrease in the number of particles with smaller radii and the coarsening of large particles with the expense of these smaller particles with increase in annealing time.



(a) (b)

Figure 3 *The probability density of α particles at (a) 423 K and (b) 373 K.*

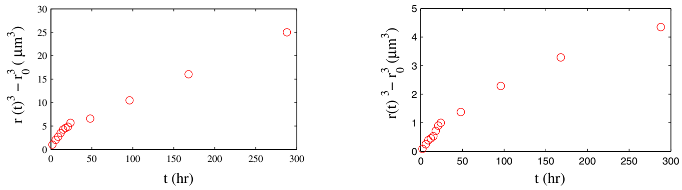
The scaled cumulative size distributions ($F(\rho)$) of α particles as a function of annealing time at 423 K and 373 K are shown in Fig. 4. The scaled radius used here is $\rho = r_i/\bar{r}$ where r_i is radii and $\bar{r}$ the average size of particles. It is expected that if the solder system would show scaling the distribution curve would superimpose on each other but the distribution curves did not superimpose within the max. annealing time used in this experiment.



(a) (b)

Figure 4 *Scaled cumulative size distribution of α particle at (a) 423 K and (b) 373 K.*

Fig.5 shows the evolution of particle at 423 K and 373 K. Ostwald ripening, the only analytical theory available describing the coarsening of such particles predicts that the growth follows a scaling law: $r(t)^3 - r0^3 = kt$. Clearly the results are not in accordance with a simple scaling law, as two regions are evident.



(a) (b)

Figure 5 *The time dependence of the α-particle size at (a) 423 K and (b) 373 K.*

Conclusions

Dissolution, coalescence, and dissociation of particles have been observed in the overall coarsening process. The coarsening did not show scaling of the distribution function. The spatial distribution of particles could play a vital role in the coarsening process.

PO Box 513, 5600 MB Eindhoven, the Netherlands