that the traditional AFD formulation is not accurate in predicting void nucleation sites in a very thin film structure. Therefore, they proposed a modified AFD formulation by introducing a volume-averaged stress concept for investigating the void nucleation sites and the void growth process in copper dual damascene interconnects. In addition, Li et al. (2008) and Li and Basaran (2009) proposed a model for simulating the damage mechanics of EM and TM and their interaction. The governing equations utilised for the model include mass conservation, force equilibrium, heat transfer and electricity conduction.

In reality, the atomic mass transport is caused by a combination of interacting driving forces, which can generate voids at different locations. These driving forces are induced from different physical phenomena such as momentum exchange with current carriers (electron wind), temperature gradients, mechanical stress gradients, and atomic density gradient (ADG) (or more general, of the chemical potential) (Tan and Roy, 2006; Liu et al., 2010). However, the traditional AFD method neglects the effect of the ADG. We need to find out what would be the impact on the fundamental mechanism of the EM if the ADG is neglected and how significant the effect of the ADG would be in both interconnects and solder joint system of a wafer level chip scale package (WL-CSP). In this paper, we will investigate the AFD method and the impact of the ADG on the divergences of the atomic fluxes. The comparison of results with and without considering the ADG is discussed in details.

To simplify the problem, only the electron wind, temperature gradients and ADGs are considered in this work. Therefore, the atomic flux due to thaaoons. T20TD3.3428 T 084.3(n wi)3.7(n)4.51.1976 TD-

From the atomic flux equation (1a) to equation (1c), the divergence of the respective atomic fluxes can be derived as

$$\text{div } J_A \quad \frac{E_a}{kT} \frac{1}{T} \quad \frac{0}{} \quad J_A \quad T \quad \frac{1}{c} J_A \quad c \tag{2a}$$

$$\text{div } J_{Th} \quad \frac{E_a}{kT^2} \frac{3}{T} \quad \frac{0}{} \quad J_{Th} \quad T \quad \frac{cQ^* D}{3k^3 T^3} j^2 \quad {}^2 e^2 \quad \frac{1}{c} J_{Th} \quad c \tag{2b}$$

$$\text{div } J_C \quad \frac{E_a}{kT} \frac{T}{T} J_C \quad D \text{ div}( \quad c) \tag{2c}$$

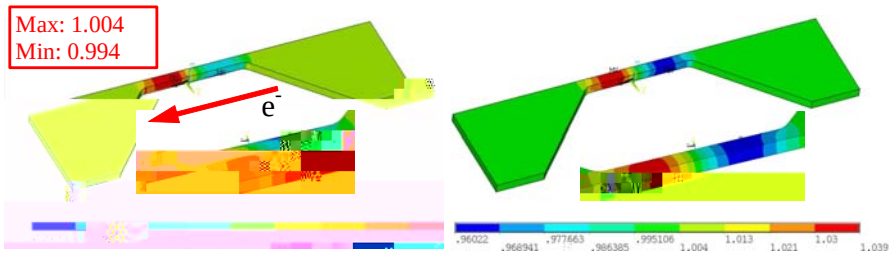
$$\text{div } J_{Total} \quad \text{div } J_A \quad \text{div } J_{Th} \quad \text{div } J_C \tag{2d}$$

Based on the mass balance mechanism, the time dependent evolution equation of a local atomic density can be written as:

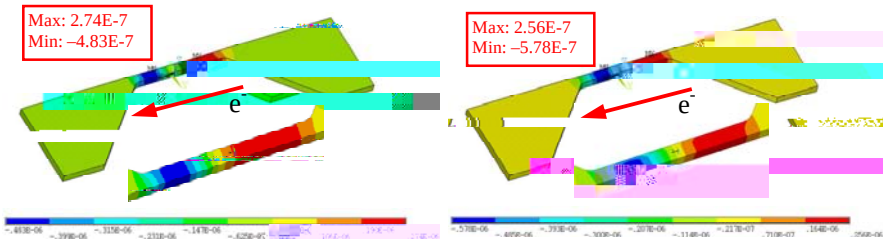
$$\text{div } J_{Total} \quad \frac{c}{t} \quad 0 \tag{3}$$

In conventional AFD method (Dalleau and Weide-Zaage, 2001; Tan et al., 2007), the effect of ADG $c$

Normalised atomic density distribution of the SWEAT structure at different time, (a) at time = 1E + 4 seconds (b) at time = 1E + 5 seconds (c) at time = 1E + 6 seconds (see online version for colours)

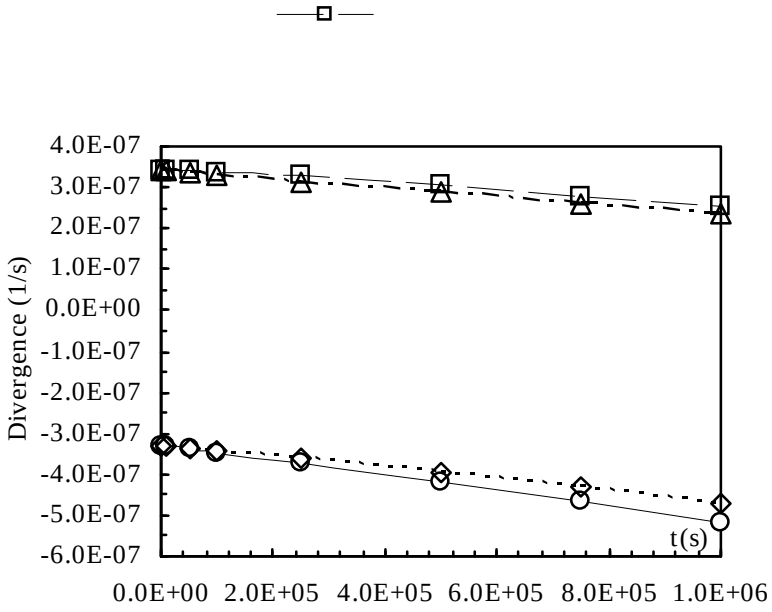


The total atomic flux divergence distribution of SWEAT structure with and without consideration of atomic density gradient at time = 1E6 s (unit: 1/s), (a) with ADG: $\mathrm{div}(J_{Total})$ (b) without ADG: $\mathrm{div}(J_{Total})$ (see online version for colours)

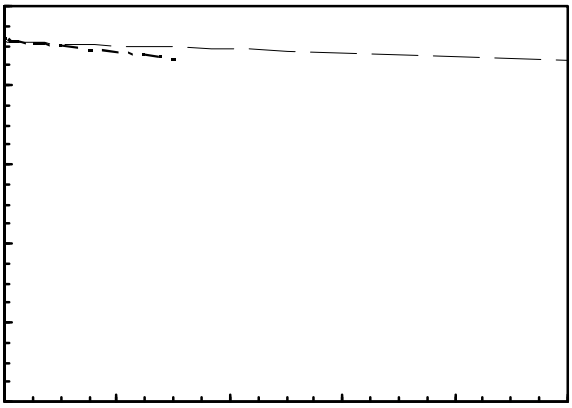



(a) (b)

The divergences of atomic fluxes with and without considering ADG at nodes 914 and 1,295, (a) selected two nodes: 914 in cathode and 1,295 in anode (b) the AFD curves with electron wind migration only (c) AFD curves with electron wind and thermal migration (d) total AFD curves comparison [equation (2d) and equation (4c)] (continued) (see online version for colours)

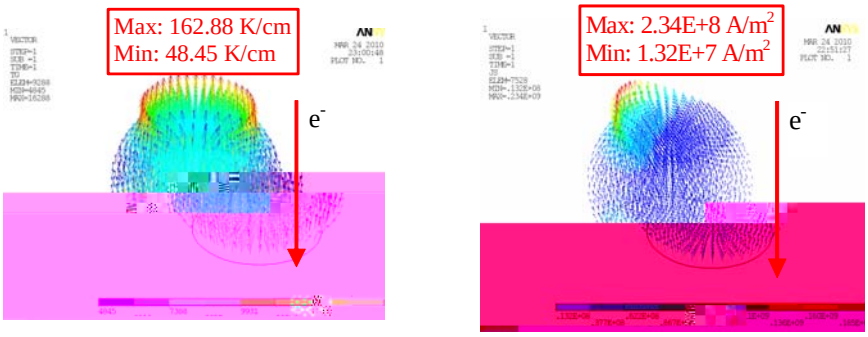


The divergences of atomic fluxes with and without considering ADG at nodes 914 and 1,295, (a) selected two nodes: 914 in cathode and 1,295 in anode (b) the AFD curves with electron wind migration only (c) AFD curves with electron wind and thermal migration (d) total AFD curves comparison [equation (2d) and equation (4c)] (continued) (see online version for colours)



Their related thermal mechanical and electrical constants used in the simulation are taken from references (Chiang and Lee, 2006; Lai et al., 2007; Liu, et al., 2010) as listed in Table 3. The EM parameters and ANAND parameters of 95.5Sn4.0Ag0.5Cu solder bumps are listed in Tables 4 and 5 respectively (Gan et al., 2002; Chiang and Lee, 2006;

Temperature gradient and current density distribution of SnAgCu solder bump,
(a) temperature gradient (b) current density distribution (see online version for colours)




(a) (b)

Figures 13 and 14 compare the divergences of atomic flux with and without considering the ADG at time = 5E5 s. In Figure 13, the comparison of the AFD with and without considering the ADG is obtained for:

1 electron wind migration only

2 electron wind and the thermal migration.

Without considering ADG, it shows the negative AFD (blue colour) at the upper left edge of the solder ball in (b) and (d) cases, which means the hillock nucleation will appear at the upper left edge of solder bump. This is

The AFD distribution of WL-CSP structure with and without considering ADG at time = 5E5 s (unit: 1/s), (a) div($J_A$) (b) div($J_A$) (c) div($J_A$) div($J_{Th}$) (d) div($J_A$) div($J_{Th}$) (continued) (see online version for colours)

The divergences of atomic fluxes with and without considering ADG at the selected nodes 325, (a) cross section of the solder ball (b) the AFD curves with considering the ADG (c) the AFD curves without considering the ADG (see online version for colours)