

Analytical Solution for Moisture-Induced Interface Delamination in Electronic Packaging

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Abstract

In this paper a vapor pressure model based a micromechanics approach is introduced first, with which the

controlled humid environment. In stage 2, the package is mounted on to the printed circuit board by soldering. The entire package is exposed to temperatures as high as 220°C.

As a result the condensed moisture vaporizes under the

The objective of this study is to develop analytical solutions for moisture-induced delamination failures at the interface, during solder reflow process. Previous studies [3,4, 5], in which the nonlinear constitutive relation is adopted, showed that the vapor pressure plays an important role in the delamination initiation. But the model was not able to make differences on the material behaviors in bulk material and at the interface. For instances, when elastic-plastic stress-strain relation is applied, the critical stress that leads the void collapse is 4-6 times of saturated vapor pressure, both in bulk and at interface [3,4].

This paper starts with a review of the vapor pressure evolution during the elevation of temperature. Then the neo-Hookean model is introduced to describe the rubble-like large-deformation of thermoset material when the temperature

density. Assuming that the void volume fraction f is 0.05, and the saturated moisture concentration C is $1.25 \cdot 10^{-2} \text{ g/cm}^3$ for a typical epoxy-based polymer according to the measurement by Galloway et. al. [7], equation (4) gives $\rho = 820 \rho_{\text{ext}}$. This number clearly shows that how much moisture a typical polymer material could absorb. Such an amount of moisture must condense into the mixed liquid/vapor phase in material.

The following condition is used to determine the moisture state in voids at preconditioning of temperature T_0 ,

$$\begin{cases} \rho \leq \rho_g(T_0) & \text{for vapor phase at } T_0 \\ \rho > \rho_g(T_0) & \text{for mixed liquid/vapor phase at } T_0 \end{cases} \quad (5)$$

where, ρ_g is the saturated vapor density, which can be obtained

may change due to the change of the bulk volume by thermal expansion.

Three distinct cases for the vapor pressure evolution have been identified [2,3], and are shown in Fig. 2. In the following, the detailed description and derivation for the vapor pressure evolution for each case are presented, and

In case 2, the moisture in the voids is in the mixed liquid/vapor phase at *current* temperature T . Therefore, the moisture must also be in the mixed liquid/vapor phase at initial T_0 . The condition for case 2 is thus as following

$$\rho(T) \geq \rho_g(T) \quad (18)$$

or by equation (4)

$$p(T) = p_g(T_1) \frac{T}{T_1} \frac{f(T_1) (1 - 3\alpha(T - T_0))}{f (1 - 3\alpha(T_1 - T_0))} \quad (27)$$

where T_1 is determined by equation (23).

The above model includes an unknown f , the current void volume fraction. Obviously, the vapor pressure is dependent on the void deformation behaviors, and should be solved together with the governing equations of deformation.

Let's investigate the magnitude of vapor pressure for case

polymer materials using the moisture property data given by Galloway *et al* [7]. It shows that the initial void volume fraction is usually between 0.01 and 0.05.

Equation (12) can be simplified as $C \approx C_0$ when the thermal expansion is much smaller than 1. Equations (25)-(27) can then be simplified as following,

Case 1: when $C_0 / f_0 \leq \rho_g(T_0)$,

$$p(T) = \frac{C_0 p_g(T_0) T}{f_0} \quad (30)$$

interface strength at high moisture concentration and high temperature (very low k). However, for *same* material the correlation between the delamination and the moisture

$$\dot{f}_{\text{growth}} = (1-f)\dot{E}_{kk} \quad (40)$$

$$\dot{f}_{\text{growth}} = A\dot{\sigma} + B\dot{\Sigma} \quad (41)$$