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A Micromechanics-Based Vapor Pressure Model in Electronic Packages

A complete vapor pressure model based on a micromechanics approach is developed in this paper. The model can be extended to calculate the initial vapor pressure as traction loading subjected to the interfaces after the delamination. The impact of the vapor pressure induced expanison on the material's deformation is discussed.
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1 Introduction

$$\alpha_{D1} \frac{\partial C_1}{\partial n} = \alpha_{D2} \frac{\partial C_2}{\partial n} \qquad (3)$$

where 1 and 2 represent different materials, respectively, and S is the solubility. The solubility S is related to the saturated concentration C_{sat} by

$$S = C_{sat}/p_{ext} \qquad (4)$$

where p_{ext} is the ambient vapor pressure under the given humid conditions.

In order to numerically solve Eq. (1) in a multiple-material system (e.g., by finite element method), the following variable with continuity at the interface can be defined [2]

$$\varphi = C/S \qquad (5)$$

or equivalently, according to Eq. (4)

$$w = C/C_{sat} \qquad (6)$$

In order to illustrate the nature of the moisture diffusion in plastic materials, we consider an example of a simple transient moisture diffusion problem in a slab, with the boundary conditions as shown in Fig. 1. The thickness of 2 mm is taken as a typical value. The material properties (e.g., a typical mold compound), together with the ambient humid conditions for three types of moisture preconditioning are listed in Table 1 [2]. The solution can be represented as [3]

$$C(x,t) = C_{sat} \left[1 - \sum_{n=0}^{\infty} \left[\text{w} \right. \right.$$

$$f = \frac{dV_f}{dV} \quad 0 < f \leqslant 1 \tag{11}$$

The following relation between ρ and C can be obtained

$$\rho = \frac{\mathrm{d}m}{\mathrm{d}V_f} = \frac{\mathrm{d}m}{\mathrm{d}V}\frac{\mathrm{d}V}{\mathrm{d}V_f} = C/f \tag{12}$$

As discussed before, the saturated moisture concentration C_{sat} =$41\rho_{\text{ext}}$ at $85\,^{\circ}\text{C}/85\text{RH}$ condition for a typical mold compound. Assume that the void volume fraction f is 0.05, Eq. (12) gives ρ =$820\rho_{\text{ext}}$. This number clearly shows that how much moisture a

$$C_0/f_0 > \rho_g(T_0) \text{ and } \frac{C_0}{f}[1 - 3\alpha(T - T_0)] < \rho_g(T) \qquad (30)$$

The phase transition temperature T_1, where the moisture is just fully vaporized, should be determined first according to Eq. (14), which can be rewritten as

$$\frac{C_0}{f(T_1)}[1 - 3\alpha(T_1 - T_0)] = \rho_g(T_1) \qquad (31)$$

Then from T_1 to temperature T the Eq. (18) can be used with the reference state (p_r, f_r, T_r, C_r) to be substituted by $(p(T_1), f(T_1), T_1, C(T_1))$, as follows:

$$p(T) = p(T_1)\frac{T}{T_1}\frac{f(T_1)C}{fC(T_1)} = p_g(T_1)\frac{T}{T_1}\frac{f(T_1)C}{fC(T_1)}$$

$$= p_g(T_1)\frac{T}{T_1}\frac{f(T_1)}{f}\frac{1 - 3\alpha(T - T_0)}{1 - 3\alpha(T_1 - T_0)} \qquad (32)$$

Now the equations for calculating the vapor pressure are complete, which can be summarized as follows:

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

$$p(T) = \frac{C_0 p_g(T_0)}{\rho_g(T_0)f}\frac{T}{T_0}[1 - 3\alpha(T - T_0$$

rated vapor pressure, i.e., $p=p_g(T=220\,^\circ\mathrm{C})=2.32$ MPa. The vapor pressure with such a magnitude has significant effect on the void behavior, which was discussed in Ref. [7].

Questions remain that how to measure the initial void volume fraction f_0. An approximate method in estimating the initial void volume fraction was proposed [6] by using the moisture absorption test. FroT8tion

the delaminated surfaces. After the moisture-diffusion modeling is performed, the averaged moisture concentration can be calculated according to Eq. (44). When

$$C^{\text{ave}} \geqslant \rho_g(T) \qquad (45$$