MODELING OF VAPOR PRESSURE DURING REFLOW FOR ELECTRONIC PACKAGES

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Abstract

The plastic materials in electronic packages have high porosity and are susceptible to the moisture absorption. In order to investigate the moisture vaporization during reflow, the representative volume element (RVE) approach, by which the micro-void effect can be taken into consideration, is introduced in this paper. A theoretical model is established to calculate the whole-field vapor pressure in plastic materials. FEA models are built for both flip chip BGA (FCBGA) and wire bond PBGA packages to predict the moisture distribution, followed by the calculation of vapor pressure distribution in the package. Results show that the vapor pressure saturates much faster than the moisture diffusion, and a near uniform vapor pressure is reached in the package. The vapor pressure can’t exceed the saturated pressure at the corresponding temperature, even when more moisture is added in. The vapor pressure introduces additional mismatch to the package, which is directly related to the vapor pressure distribution, rather than the moisture distribution. Moisture desorption during reflow is also studied and it has significant effect on the moisture distribution, but not on the vapor pressure distribution. A complete solution for the vapor pressure subjected to the interface after delamination is also derived.

1. INTRODUCTION

The moisture-induced failures, e.g., popcorn and delamination, of IC packages are common phenomenon during solder reflow. The failures are
due to sudden vaporization of moisture absorbed by the package at high temperature condition. Therefore, it is critical to evaluate the strength of internal vapor pressure generated in the package during reflow. The popcorn failure was first postulated by Fukuzawa et al. [2] in 1985, and later supported by many publications [1, 3, 6-8].

JEDEC standard [5] is widely used to conduct reliability test on moisture sensitivity of the electronic packages. Kitano et al. [6] showed that the package cracking is not controlled by the absolute water weight gain, rather it is due to the local moisture concentration at the critical interface. Therefore, the moisture diffusion modeling is required. However, the modeling of ensuing vapor pressure within the package during the reflow is the key element in understanding the failure mechanism. Previous researchers [3, 6-8] assumed that the delamination exists before the reflow, and considered the vapor pressure as traction loading subjected to the delaminated interfaces. Since the vapor pressure is generated anywhere in the package, it is necessary to investigate the whole field vapor pressure distribution before the package delamination.

2. VAPOR PRESSURE BEFORE DELAMINATION

For plastic materials such as mold compound, the saturated moisture concentration ($C_{sat}$) is a few orders larger than the corresponding saturated ambient water vapor density during the moisture preconditioning, e.g., $\rho_g$, at 85°C/85%RH (see Table 1). This implies that the moisture absorbed by plastic materials must be condensed into water in the micro-voids or free-volume of the materials. During the reflow, the moisture vaporizes at high temperature and produces internal vapor pressure. The vapor pressure, however, can not go beyond its saturated pressure as long as the moisture in the voids is not fully vaporized.

In order to estimate the vapor pressure generated inside the material, the Representative Volume Element (RVE) approach is introduced here. Let's take a very small representative material sample of volume $dV$, termed RVE as shown in Fig.1 [4]. From the microscopic level, the RVE is large enough to be statistically representative of the material properties at this location. Assume that the total volume of voids in this RVE is $dV_f$. Since the initial micro-voids are distributed randomly but uniformly in the material, the ratio $f_0 = dV_{f0}/dV$, defined as initial void volume fraction, is considered as a material property. The void volume fraction $f$ at current state during reflow thus can be defined by

$$f = \frac{dV_f}{dV}$$  \hspace{1cm} (1)

where $dV_f$ is the current void volume and $dV$ is the element volume.