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[10]. Hence it is important to understand the moisture redistribution, transport, and diffusion during the reflow process. It was found that the normalization approach cannot be applied to a loading condition with varying ambient temperature and/or humidity, such as in reflow.

**2.2 Direct Concentration Approach.** Now consider a general case in which the solubility  $S$  varies with time  $t$ . A simple transformation from Eq. (6) to Eq. (7) does not exist, but is given by

$$\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2} = \frac{1}{D} \frac{\partial}{\partial t} + \frac{\partial S}{D \cdot S \partial t} \quad (9)$$

in which

$$\frac{\partial S}{D \cdot S \partial t} \neq 0 \quad (10)$$

Similarly,

$$\frac{\partial^2 w}{\partial x^2} + \frac{\partial^2 w}{\partial y^2} + \frac{\partial^2 w}{\partial z^2} = \frac{1}{D} \frac{\partial w}{\partial t} + \frac{w}{D \cdot C_{\text{sat}}} \frac{\partial C_{\text{sat}}}{\partial t} \quad (11)$$

in which

$$\frac{w}{D \cdot C_{\text{sat}}} \frac{\partial C_{\text{sat}}}{\partial t} \neq 0 \quad (12)$$

when the saturated moisture concentration  $C_{\text{sat}}$  becomes dependent on time  $t$ . In Eqs. (9) and (11),  $S$  or  $C_{\text{sat}}$  is assumed coordinate-independent for simplification.

Equations (9) and (11) indicate that a simple thermal-moisture analogy does not exist when ambient temperature or humidity varies with time (or temperature). For a reflow process, the ambient humidity condition can be assumed constant (zero), but temperature changes with time. In this case, Eq. (10) holds true.

Equation (11) can be reduced to Eq. (8a) only when the saturated moisture concentration is a constant. For most polymer materials, it was found that  $C_{\text{sat}}$  is relatively independent of temperature, but RH [1]. Figure 2 is an example of the saturated moisture concentration in a bismaleimide-triazine (BT) sample as a func-

absorbed by water-polymer affinity due to the availability of hydrogen bonding sites along the polymer chains and interfaces, which are known as "bound water." Unbound moisture will vaporize during reflow. In order to determine the vapor pressure, it is necessary to determine if moisture is in vapor phase or binary

using the DCA according to the procedures described above. It is noted that the constraint equations at the interface from steps 1 to 2 must be updated accordingly.

In order to validate the numerical results, Mat2 is considered as a nonabsorbing material. This is realized by assigning the material

properties of Mat2 a few orders lower than Mat1, as shown in

fully saturated condition. The analytical solution for the problem in Fig. 7(b) can be derived as follows [16]:

$$C(x,t) = \frac{4C_{\text{sat}}}{\pi} \sum_{n=0}^{\infty} \frac{1}{(2n+1)} \sin\left(\frac{(2n+1)\pi x}{h}\right) \exp\left[-\frac{D}{h^2}(2n+1)^2 t\right] \quad (21)$$

where  $C_{\text{sat}}$  is the saturated moisture concentration of Mat1 at 60°C/60%RH,  $D$  is the moisture diffusivity at 260°C,  $h$  is the double-thickness of Mat1 (as 0.4 mm shown in the Fig. 7(b)), and  $x$  is the distance from the edge. In this example, the saturated moisture concentration at 60°C/60%RH is the same as 260°C/60%RH. In order to eliminate the temperature gradient effect, the thermal conductivity is chosen a few orders higher than the moisture diffusivity at 260°C, so that the temperature becomes rapidly uniform in a very short time period.

Figure 8 plots the comparison of the local moisture concentration at the interface as a function of time using the DCA and the

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