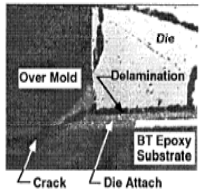
LOMSS

Investigations on Moisture Induced Reliability Issues

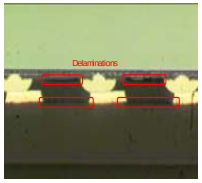
Moisture absorbed into electronic packaging polymer materials causes:

- Hygroscopic stresses
- Degradation of adhesion strength of resins used in electronic packaging
- High vapor pressure generation inside defective delaminated cavities

  → **Detrimental effect on the reliability of microelectronics packages**



Popcorn cracking in PBGA package (Galloway *et al*, IEEE CPMT-A, 1997)



Delamination of underfill by hygroscopic swelling and adhesion degradation

Characterization of fundamental hygroscopic properties: diffusion coefficient and maximum moisture weight gain (solubility)

Modeling schemes: diffusion analysis (thermal/moisture analogy), combined hygroscopic/thermal stress analysis

New measurement techniques for hygroscopic swelling coefficient (moire interferometry and DIC)

Verification of modeling schemes: Predictive Mode

Characterization of strength and moisture induced degradation of polymer and polymer interface

Development of vapor pressure modeling

Reliability assessment and prediction (VQ)

- **Combined fracture model**
- **Life cycle load**
- **Accelerated testing environments (85°/85%RH, Pressure Cooker, etc.)**
- **Virtual testing & acceleration factors**

Hygroscopic Material Properties

Moisture diffusion (Fick's law) $\dot{C} = \nabla \cdot (D \nabla C)$ $D = D_0 \exp\left(\frac{E_D}{kT}\right)$

(C: concentration, D: diffusivity, T: temperature)

Saturated concentration $C_{sat} = S \times P_v = S \times P_{sat} \times RH\%$

(C_{sat} : saturated weight gain, S: solubility, P_v: vapor pressure of ambient)

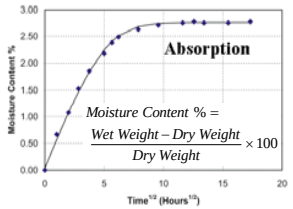
Required Properties : D *and* C_{sat} ← Measurement through moisture weight gain

Mass gained by fick's diffusion

$$\frac{m(t)}{m_{sat}} = 1 - \frac{512}{\pi^6} \sum_{l=0}^{45} \sum_{m=0}^{45} \sum_{n=0}^{45} \frac{e^{\left(-Dt\left(\frac{}{L_{eqv}}\right)^2\right)}}{(2l+1)^2(2m+1)^2(2n+1)^2}$$

$$L_{eqv}^2 = \left\{ \left[\frac{(2l+1)\pi}{x_0}\right]^2 + \left[\frac{(2m+1)\pi}{y_0}\right]^2 + \left[\frac{(2n+1)\pi}{z_0}\right]^2 \right\}^{-1}$$

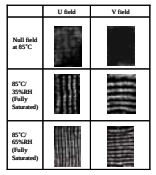
Calculation of D through non-linear regression



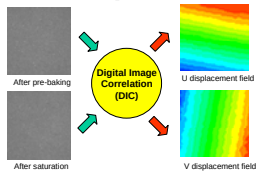
Characterization of Hygroscopic Swelling

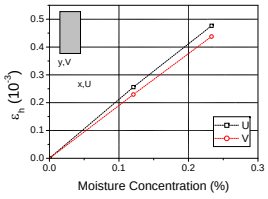
Hygroscopic swelling strain: $\varepsilon_h = \beta \times C$ where β: coefficient of hygroscopic swelling (CHS)

Thick specimen



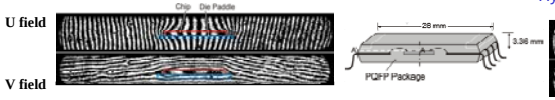
Thin specimen



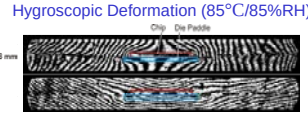


Measurement techniques for the swelling coefficient have been developed utilizing optometric tools (moiré interferometry and DIC)

Thermal Deformation by ΔT = -60°C

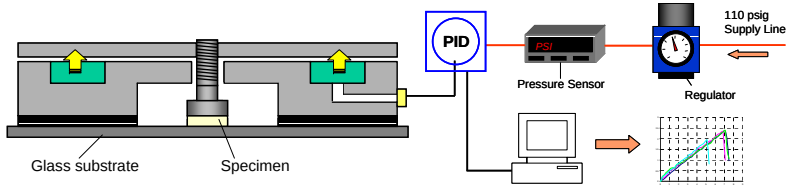


Hygroscopic Deformation (85°C/85%RH)

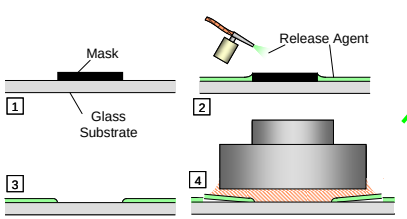


Comparable deformation by hygroscopic swelling to thermal deformation

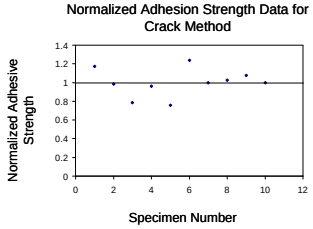
Adhesion Strength Measurement



Improved pressure-controlled adhesion strength measurement system

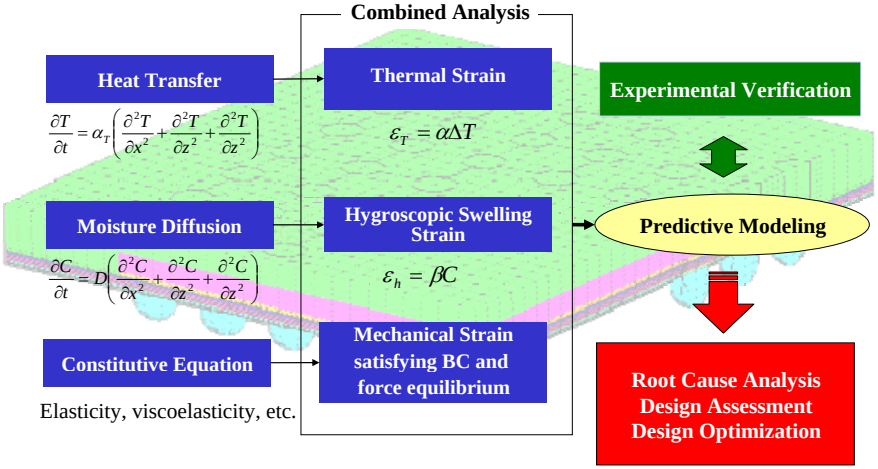


Novel method to prepare crack-controlled specimen



Substantial reduction in deviation (>100% → <25%)

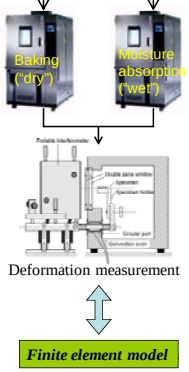
Combined Hygro-thermo-mechanical Model

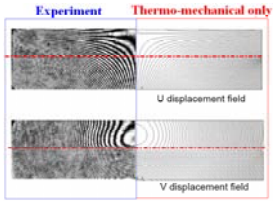


Elasticity, viscoelasticity, etc.

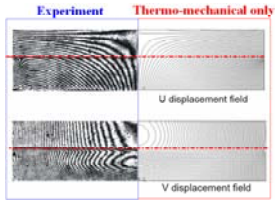
Verification of Combined Numerical Model

Bi-material specimen

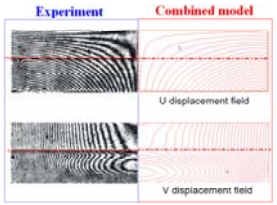




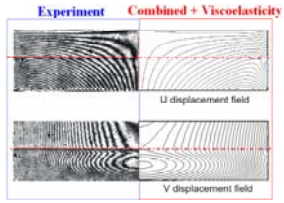
1) ΔT = 60°C & Dry → **Good agreement**



2) ΔT = 60°C & Wet → Disagreement

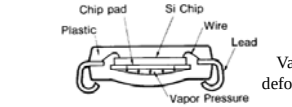


3) ΔT = 60°C & Wet → Incomplete agreement

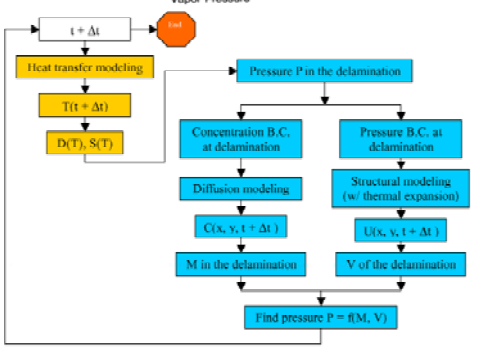


4) ΔT = 60°C & Wet → **Good agreement**

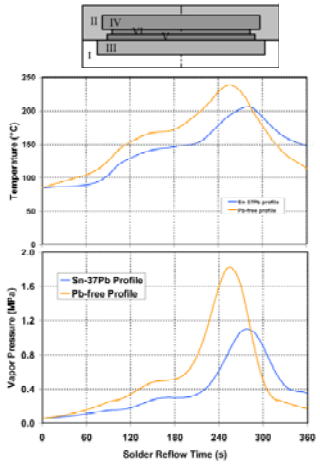
Vapor Pressure Model



Vapor pressure-induced deformation (Kitano, 1988)



Advanced FEA Implementation of Kitano's Scheme without Iteration



Application to a multi-material package subjected to reflow process

On-Going Tasks

- Characterization of hygroscopic properties beyond glass transition temperature
- Investigation on degradation of adhesion strength caused by moisture absorption
- Development of an advanced damage model including bulk and interface fracture
- Development of more rigorous vapor pressure model that includes the physical behavior of water molecule-polymer chain interactions