A Study of Temperature Dependent Coefficients of Hygroscopic Swelling of Polymers

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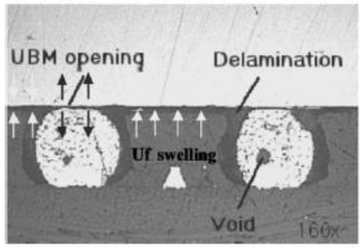
I. Motivation

- Moisture absorption induces swelling and deformation in a package and leads to failure in some cases
- Coefficient of Hygroscopic Swelling (CHS) is one of the most important material properties in studying moisture induced failure
- At β=0.1-0.4 and ΔC~0.5%, the strain is equivalent to deformation at ΔT~30-120 ºC
- This material property (a coefficient) is not readily available in literatures or vendor data sheets and rare to find in literature
  - Lack of efficient measurement methods,
  - Measurements are time consuming, and
  - Lack of knowledge of moisture diffusion mechanism.



Hygroscopic swelling of underfill and typical moisture-induced failure during HAST

(T. Y. Tee, C. I. Kho, D. Yap, C. Toh, X. Baraton, and Z. Zhong, "Reliability assessment and hygroswelling modeling of FCBGA with no-flow underfill," Microelectron. Rel., pp.741–749, 2003.)

II. CHS measurement methods

- Coefficient of hygroscopic swelling can be expressed as:

$$\beta = \frac{\varepsilon_h}{C}$$

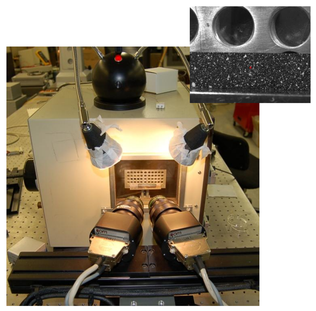
ε_h: the hygro strain (induced by absorbed moisture)
β: the coefficient of moisture expansion
C: the moisture concentration

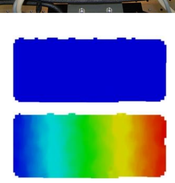
- Since it is hard to obtain the local moisture concentration, CHS, β, is mostly calculated from average strain and average moisture concentration
- CHS measurement techniques

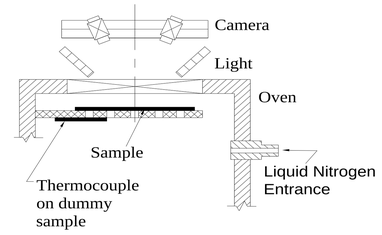
Study (Author /Year)	Test Materials	Technique
El' sadd et al./1990	Epoxy resin	Archimedean method (Fluid body displacement
Buchhold et al./ 1998	Polyimide	Bending measurement using Michelson interferometry
Wong et al./ 2000	Electronic packing underfill	Thermo-mechanical analysis and Thermogravimetry analysis
Eric Stellrecht et al./2004	Molding compound	Real-Time Moiré Interferometry
Xiaosong Ma et al./2009	Molding compound, Underfill, and die attach	DMA combined humidity generator method,

III. CHS measurement by DIC Scanning

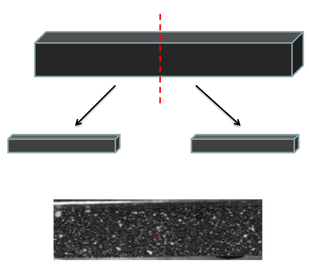
- DIC (Digital Image Correlation) measurement:
  - ❖ DIC is a full field optical deformation measurement technique in which both in-plane and out-of-plane deformations can be computed by comparing the digital images
- Hygro-strain (Measured from DIC scanning)
- Moisture concentration (TGA diffusivity measurement and FE model prediction)



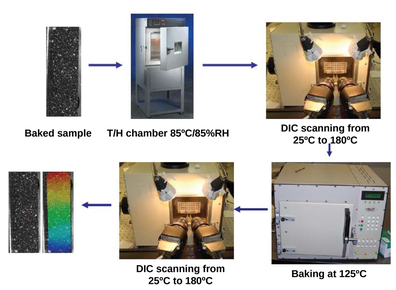


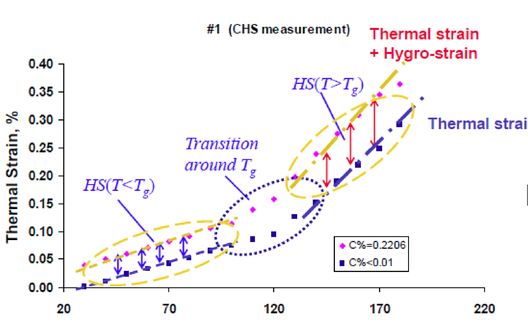


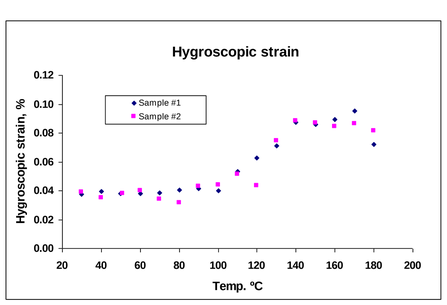
- Sample preparing for DIC scanning test
  - ➢ Testing Samples for DIC and TGA was cut from same specimen (the size of sample for DIC measurement is15x15x2mm)
  - ➢ Samples for DIC measurement were sprayed with a white paint for DIC measurement
  - ➢ All samples were first baked at 125 ºC to remove any initial moisture



- Measurement Procedure
  - ➢ Saturated the sample at 85ºC/85%RH in temperature and humidity chamber
  - ➢ The thermal expansion measurements of saturated sample were performed by DIC. The temperature range was from 25ºC to 180ºC
  - ➢ The sample then was baked at 125° C to remove moisture.
  - ➢ The expansion data for dry condition sample was obtained by DIC data for the same temperature range
  - ➢ To obtain the hygro-strain, both wet and dry condition thermal expansion data were plot in same plot and dry condition 25ºC image as reference point





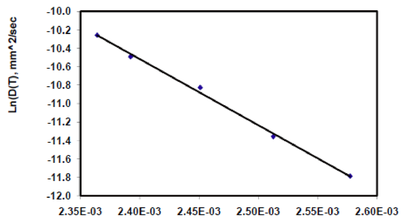


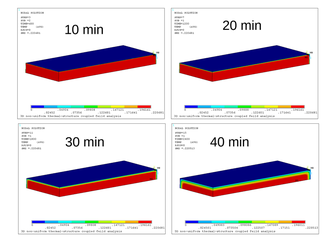
IV. Moisture Concentration Determination

- Moisture Diffusion Modeling

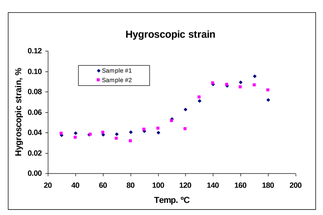
Specimens' dimensions for desorption test

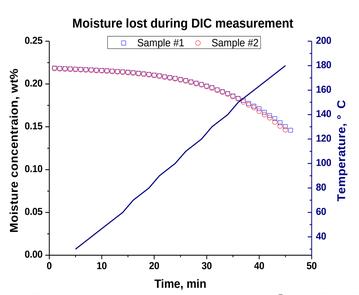
	#1	#2	#3	#4	#5	#6
X0, mm	10.35	10.36	10.36	10.35	10.37	10.36
Y0, mm	8.57	7.48	8.84	8.41	8.77	8.83
Z0, mm	2.05	2.04	2.01	2.03	2.02	2.00
Weight, mg	354.51	310.74	362.86	346.85	359.68	359.65
Heat Rate, ºC/min	20					
Temp., ºC	85	115	125	135	145	150
Moisture concentration, %C	0.23	0.24	0.24	0.23	0.23	0.24
Diffusivity, mm^2/sec	2.9219E-06	7.6047E-06	1.1685E-05	1.9883E-05	2.7752E-05	3.5101E-05

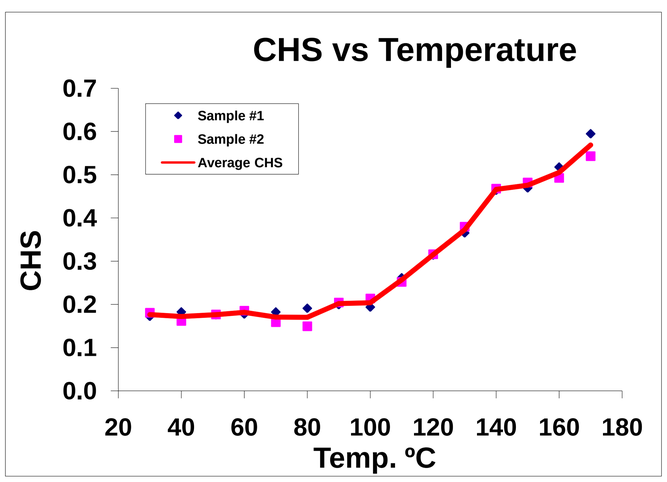




V. Results and Conclusion







- **CHS measurement by DIC scanning was introduced and its expediency was demonstrated. The method is quick and expedient as only two DIC scanning are necessary for measurements of CHS values for a wide temperature range**
- **The CHS measurement results from 25ºC to 180ºC clearly shows CHS is highly temperature dependent, especially at higher temperatures, while it is nearly constant at lower temperatures**

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