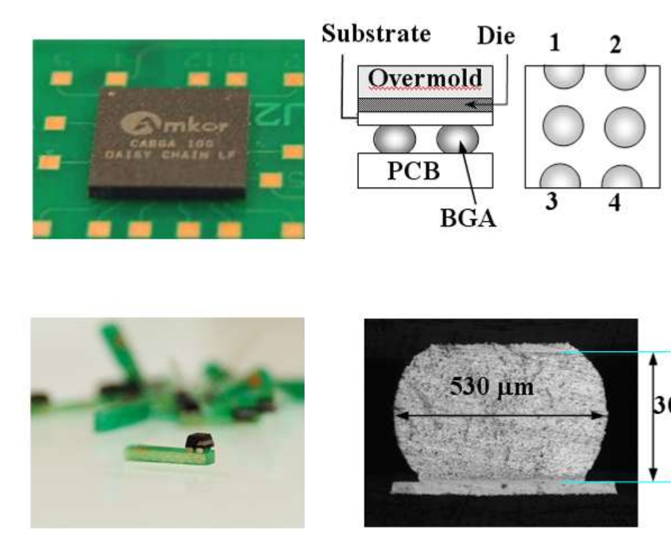
Material Characterization of Actual SAC Solder Joints Using DIC

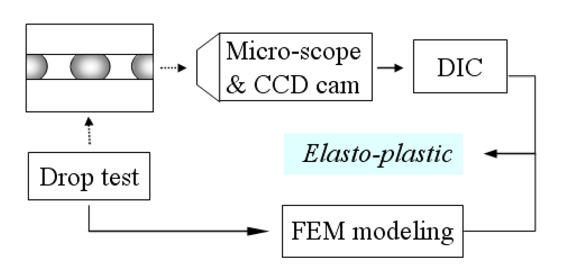
Tung T. Nguyen and Seungbae Park
Department of Mechanical Engineering, SUNY Binghamton, Binghamton NY 13902

INTRODUCTION

1. **Material properties of SAC are needed to support modeling**
   - Elastic, time-independent, time-dependent plastic (creep)
2. **Why actual solder joints?**
   - Bulk solder and solder joints have different microstructures
3. **State-of-the art**
   - There are many published data for bulk solder
   - However, data for actual solder joints are not available yet
4. **Elastic and time-independent plastic properties of SAC105, SAC305, and SAC405 were measured in this work**
5. **Methodology**
   - Combining compressive, drop test, DIC and FEM modeling

TEST VEHICLE





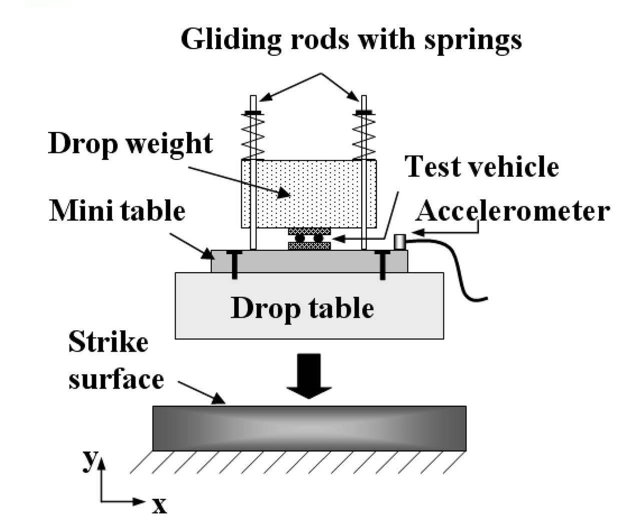
- The test vehicle: CABGA
- Packages were cross-sectioned & polished using 320-1200 grit silicon carbide papers
- Cross-sectioned surfaces exhibit random speckle pattern for DIC → No further treatment is needed

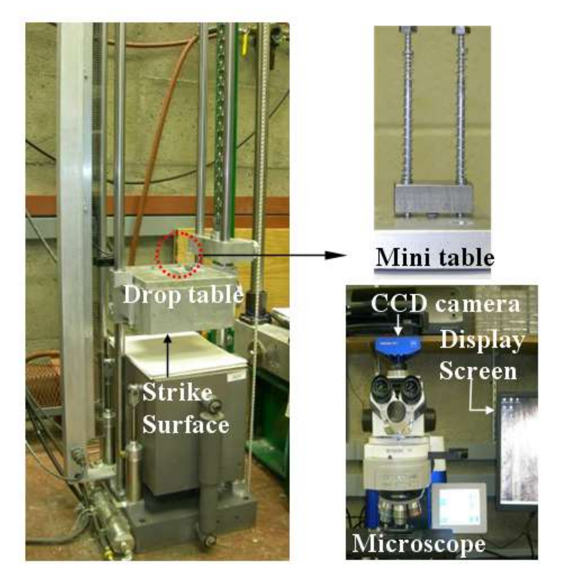
EXPERIMENTS

Micro-scope & CCD cam → DIC; Drop test; Elasto-plastic; FEM modeling

- Drop weight technique was used to create compressive force on the BGA
- Images of solder joints were taken before and after each drop using microscope

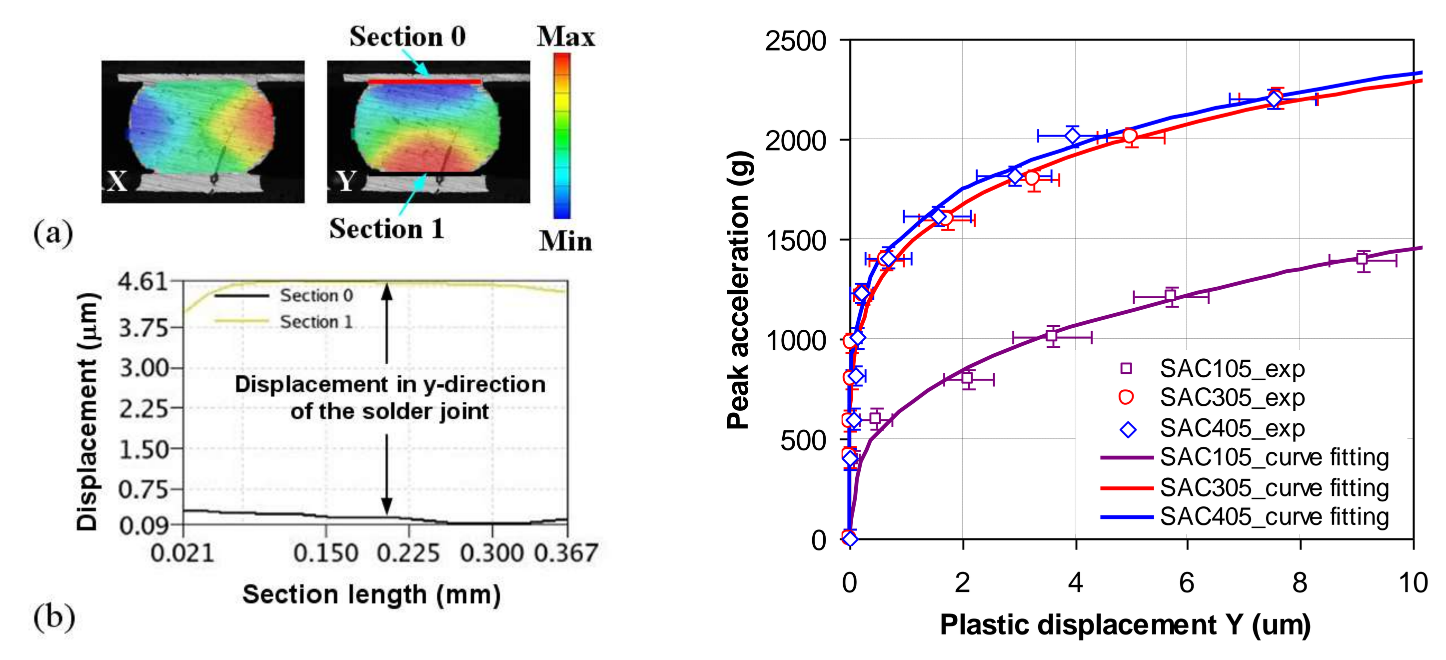
- Plastic displacement & strain in the BGA were evaluated using DIC
- A mini-table was specially designed for the drop tests
- An accelerometer was used to monitor the transient acceleration
- Drop tests with peak acceleration 400G–3000G were performed





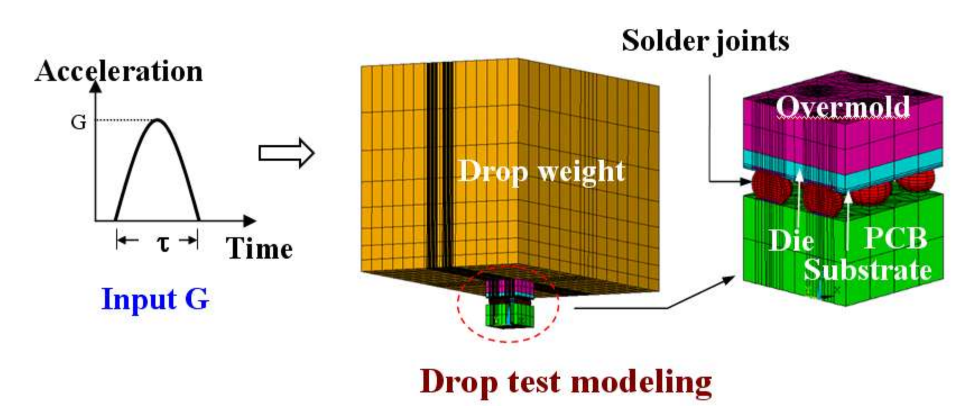
EXPERIMENTAL RESULTS

- Contour plot depicts well behavior of BGA under compression
- Displacement Y: Difference between values of section 0 and 1
- Displacement of a sample is the mean value of the solder balls
- No separation of elastic plastic displacements is needed



FEM MODELING

- Analysis: Transient
- Method: "G-Input"
- Elasto-plastic model: Multi-linear kinematic hardening (TB,KINH) for the solder joints



ITERATION PROCESS

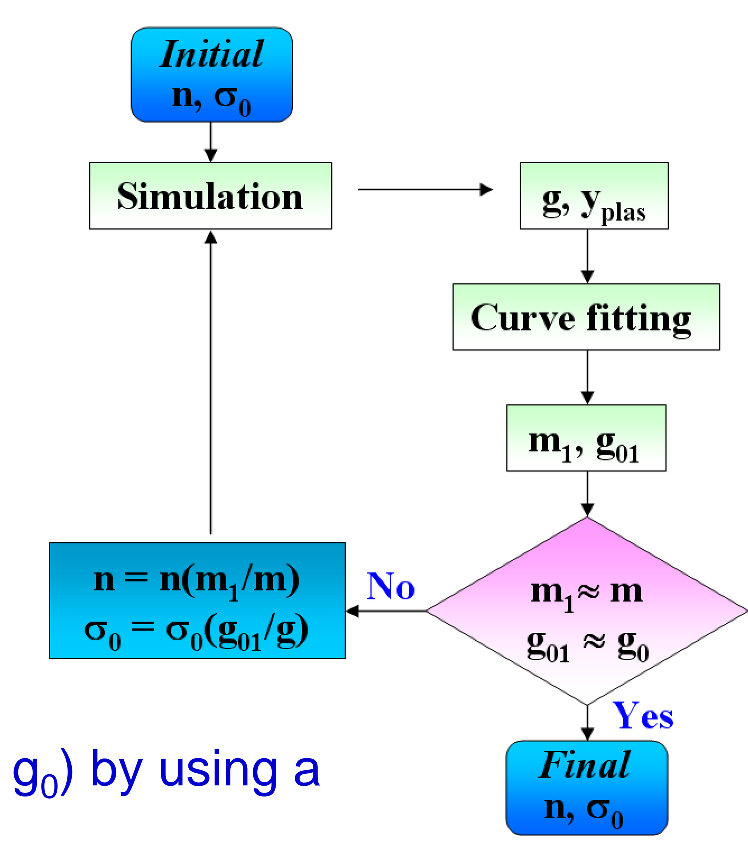
- Ramberg-Osgood Equation

$$\varepsilon = \frac{\sigma}{E} + \left(\frac{\sigma}{\sigma_0}\right)^n$$

- Curve fitting (G, Y_{plas})

$$y_{plas} = \alpha\left(\frac{g}{g_0}\right)^m$$

- (m, g_0) were obtained by fitting the experimental data
- (n, σ_0) were extracted from (m, g_0) by using a developed iteration process



RESULTS & DISCUSSIONS

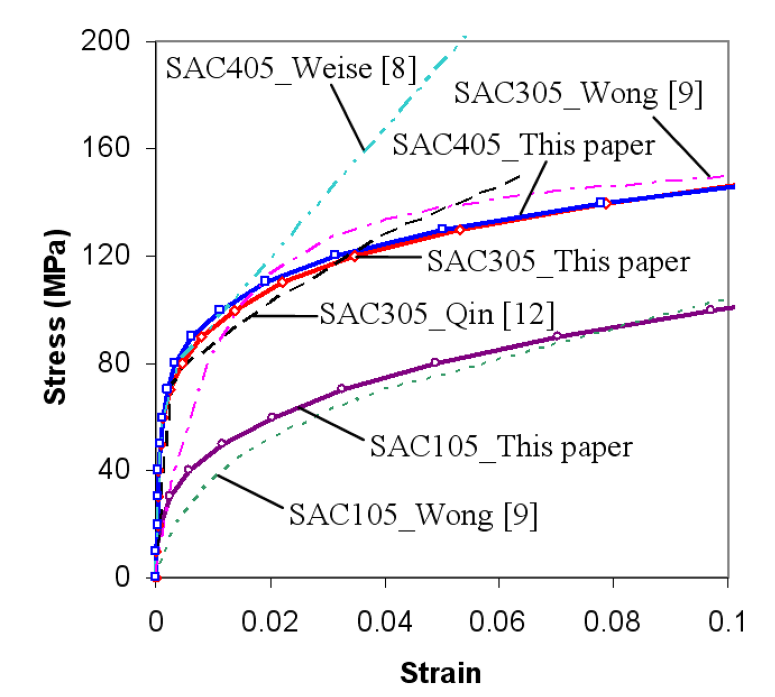
Constitutive Equations

SAC105 $\varepsilon = \frac{\sigma}{97} + \left(\frac{\sigma}{213}\right)^{3.1}$

SAC305 $\varepsilon = \frac{\sigma}{90} + \left(\frac{\sigma}{232}\right)^{5.4}$

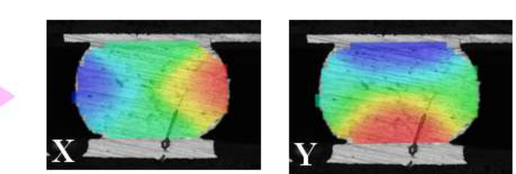
SAC405 $\varepsilon = \frac{\sigma}{86} + \left(\frac{\sigma}{215}\right)^{6}$

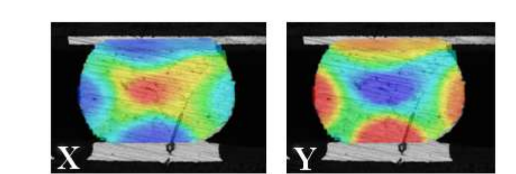
Stress-strain curves



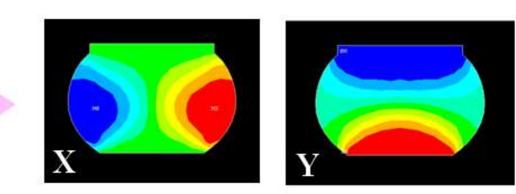
Plastic displacement | Plastic strain

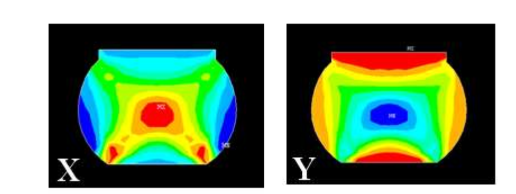
Experimental





Numerical





- Constitutive equations for SAC105, SAC305, and SAC405 solder joints were successfully developed
- The results in this work are in good agreement with literature
- Contour plots from DIC and drop modeling match very well

CONCLUSIONS

- A novel methodology was developed for the characterization of elasto-plastic behavior of SAC solder alloys
- The Ramberg-Osgood model is able to describe the elasto-plastic behavior of the solder alloys
- The coefficients of the model were successfully extracted with high accuracy
- The model was recommended to be used for drop test modeling of electronic packaging

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