Effect of Various Operating Conditions on the Low Cycle Fatigue of Bulk SAC 305 Solder

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Background & Motivation:

- Due to environmental and health concerns surrounding lead-based solder, it is becoming increasingly important to integrate lead-free solder, such as SAC 305 (96.5% Sn by weight, 3.0% Cu, 0.5% Ag)
- Bulk material properties of SAC 305 are not well documented but critical to understanding performance in non-microelectronic settings and improving the reliability of devices using SAC 305 solder

Goals of Research:

- Develop a low cycle fatigue model with frequency, temperature, and stress ratio dependencies to further understand the fatigue performance and material properties of SAC 305
- Observe the influence of stress amplitude on fracture surfaces using Scanning Electron Microscopy (SEM)

Experimental Procedures:

Fatigue Testing:

- Bulk SAC 305 solders (Canfield Technologies) were machined into dog bone shaped samples according to ASTM-E8 and all test specimens were annealed at 75°C for 1 hour and tested using MTS 810 uniaxial system
- 41 samples were successfully tested under the following testing conditions:
  - Command Stress Amplitudes ranging from 30 MPa to 100 MPa
  - Temperature: 25°C, 50°C, 100°C
  - Stress Cycle Frequency: 1 Hz, 0.5 Hz, 0.1 Hz, 0.01 Hz

SEM Analysis:

- Ten micrographs obtained from various locations on each fracture surface were used to calculate average void size. Examples of these micrographs are shown above.
- Results of the Image J analysis are presented in the table below.
- More samples must be tested to adequately verify results

Summary & Conclusion:

- Several specimens were subjected to fatigue failure under varying testing conditions, and SN curves were generated
- Effect of various testing conditions on the fatigue life were studied:
  - As specimen temperature increases or frequency of stress cycles decreases, fatigue life decreases
  - Due to defects caused during fabrication of specimens, limited test data and experimental/human error, accurate models for SAC 305 were not established
- The mode of failure for both the fatigue and tensile samples was the initiation, propagation and coalescing of micro-voids
- From the SEM analysis, samples tested under larger stress showed the presence of more micro-voids that are smaller in size compared to samples tested at lower stresses
- Large voids and a small sample sizes caused a significant difference between mean and median void size and large standard deviation values. More samples must be tested to adequately verify results