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Mechanical Behavior of Gold Containing SAC396 Solder

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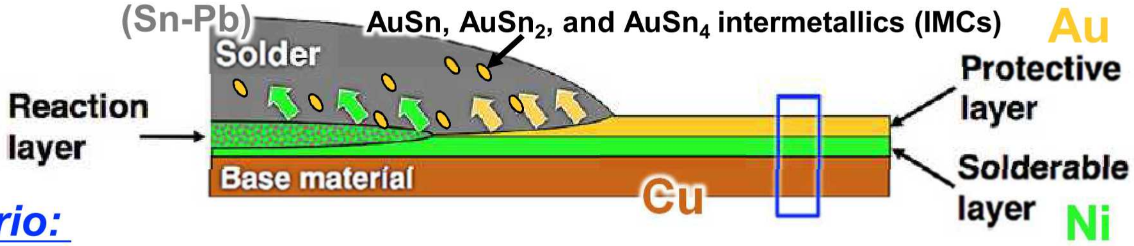
2 Au-Embrittlement Mechanisms

- **Au layer is essential to preserve solderable surface during storage, prior to soldering. However, Au can be detrimental to the reliability of solder joints**
- **AuSn, $AuSn_2$, and $AuSn_4$ intermetallics (IMCs) are brittle, therefore undesirable, BUT if distributed evenly throughout bulk solder, their presence is generally not a huge concern to joint reliability.**



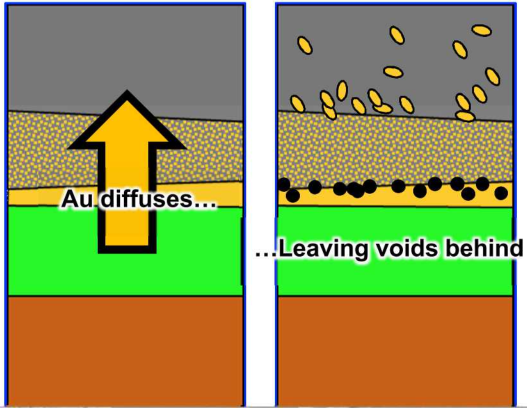
Ideal Scenario:

-Ni-Sn IMC will form metallurgical bond between solder and solderable surface

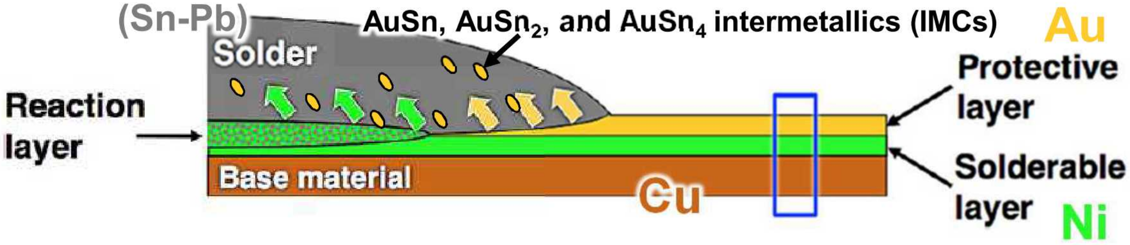
-All Au is dissolved into molten solder and a small fraction of dispersed AuSn IMCs form in the bulk solder

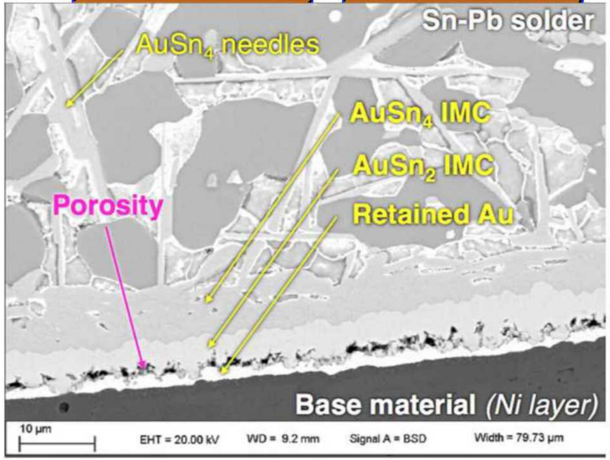
2 Au-Embrittlement Mechanisms

- **Retained Au diffuse into the solder joint over time (solid-state), leaving voids**
- **The voids link up, causing interfacial failure**

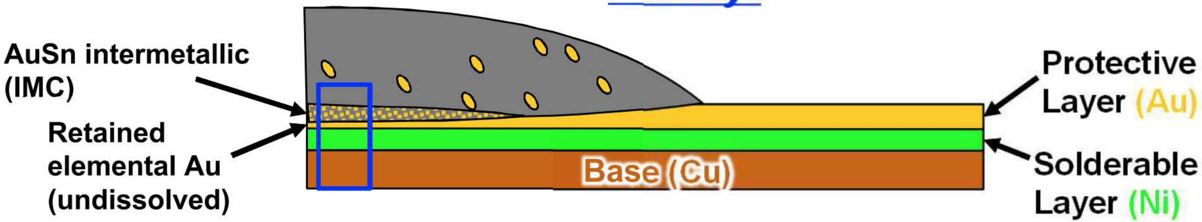


Ideal:



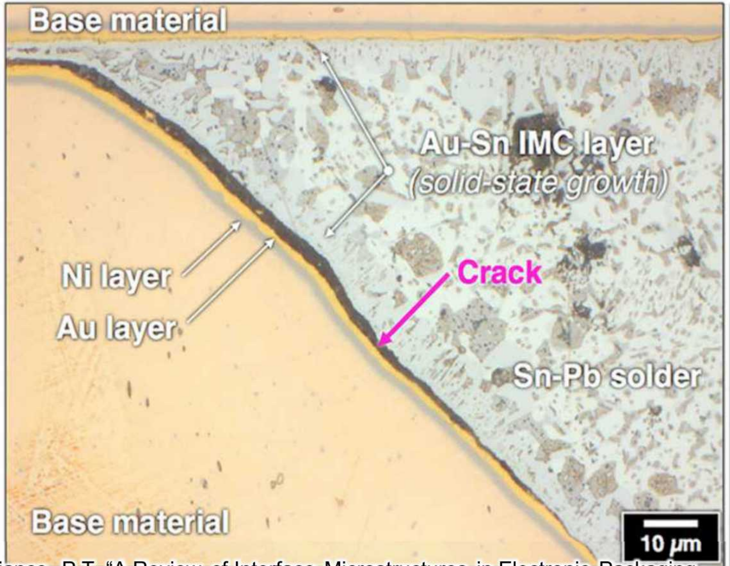


Reality:



Vianco, P.T. "A Review of Interface Microstructures in Electronic Packaging Applications: Soldering Technology." *JOM, 71* (1) 2019.

Crack formation occurs along the Au/$AuSn_4$ interface created by solid-state reaction when the Sn-Pb soldering process failed to dissolve away all of the Au protective layers from the base materials.



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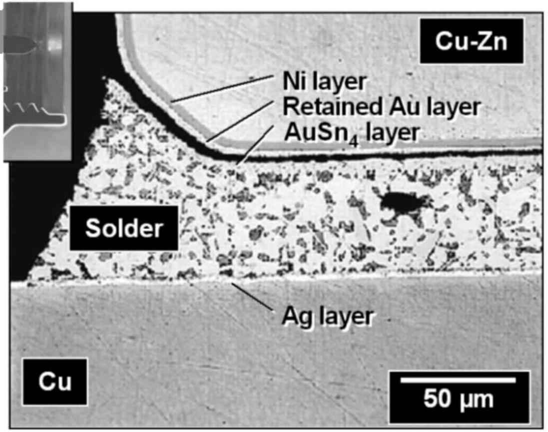
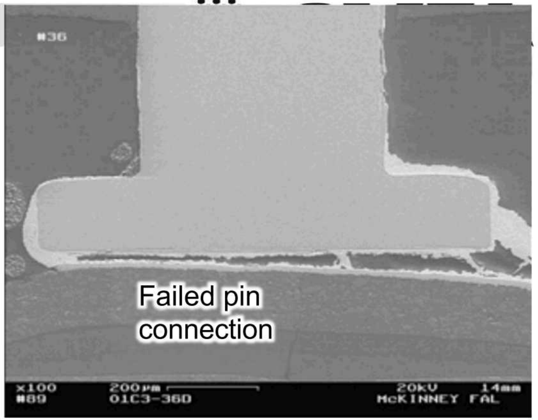
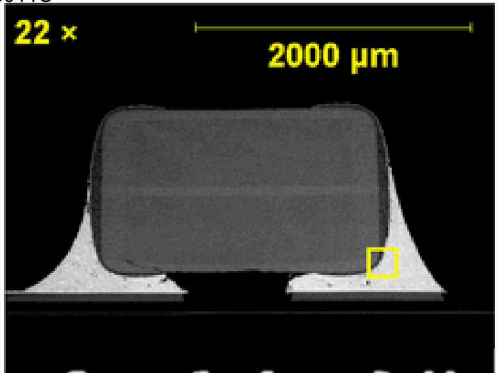


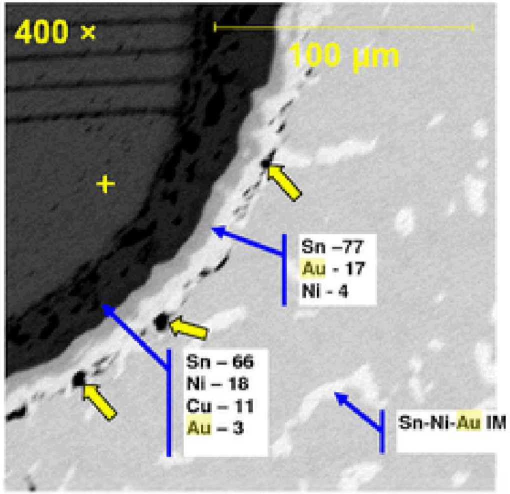
Susan, D., et al. "Microscopy of Solder Joint Failures Due to Gold Intermetallic Embrittlement." SAND2005-5011C



Wolverton, M. "Solder Joint Embrittlement Mechanisms, Solutions, and Standards." Raytheon, 2014.



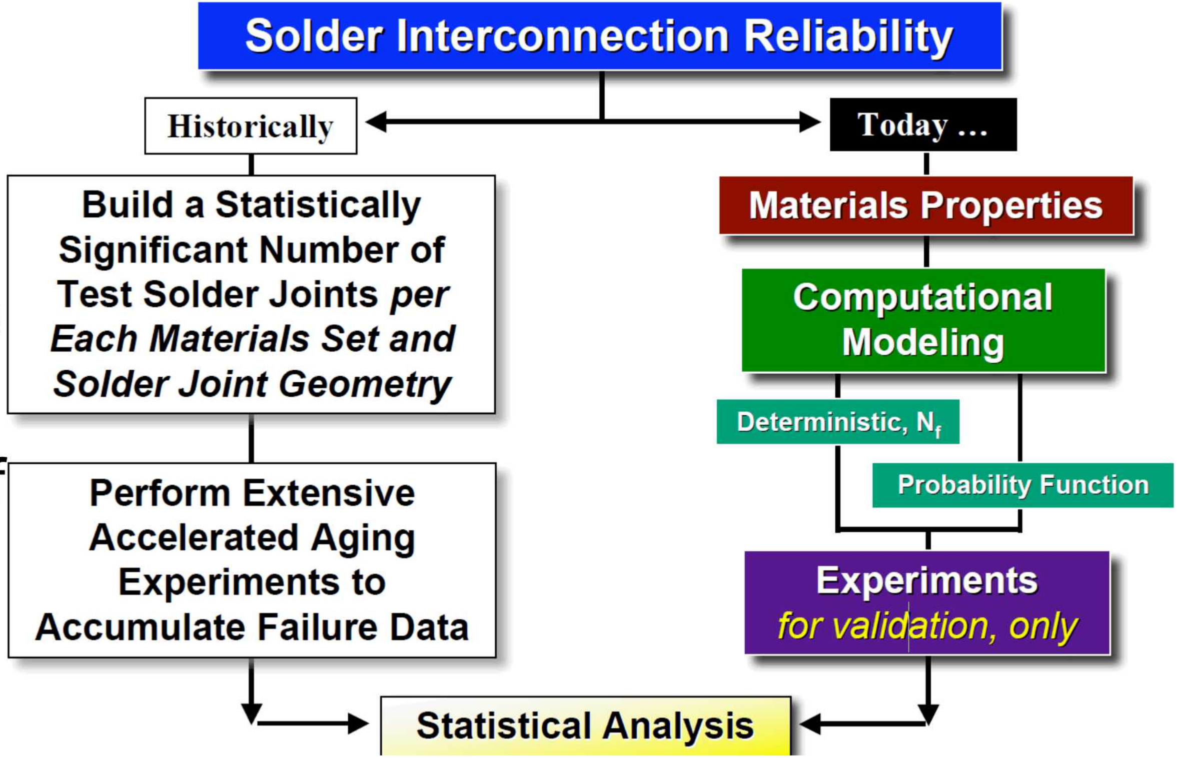
Cross-section of a capacitor (a), and a closeup of the voids formed as embrittlement progresses (b)



Asrar, N. "Lead-free Solder/Gold Metallization Interdiffusion in Electronic Interconnects: Challenges and Control." *ISTFA 2008: Proceedings from the 34th International Symposium for Testing and Failure Analysis*. ASM International, 2008.

Materials Properties

- Accurate materials properties are required to produce accurate computational models
- This study aims to generate properties of Au-contaminated SAC396 for futureTMF model development

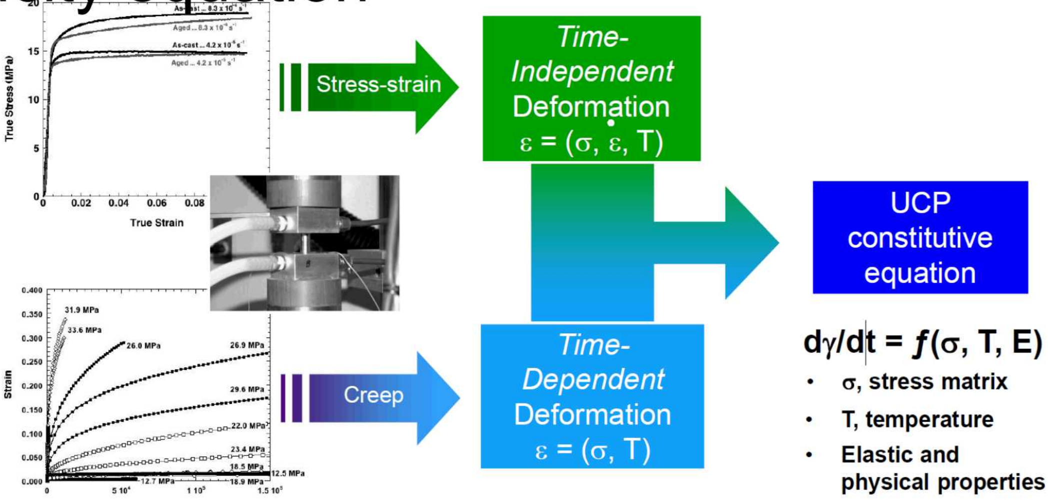


Scope of Study

- Long-term:
  - **A high level overview of mechanical behavior trends which accompany Au-content increases**
  - Apply mechanical behavior data to current LCF models and develop initial HCF predictive model
  - Validation study to compare the model with experimental, HCF failures in solder joints of electronic assemblies
  - Advance modeling capability to couple the initial HCF model with Au diffusion data to account for Au diffusion in solder joints.

Elasticity and Plasticity

- Elastic (time-independent and plastic (time-dependent deformation will both influence thermomechanical fatigue behavior
- Modeling approach is based on the development of a unified creep-plasticity equation

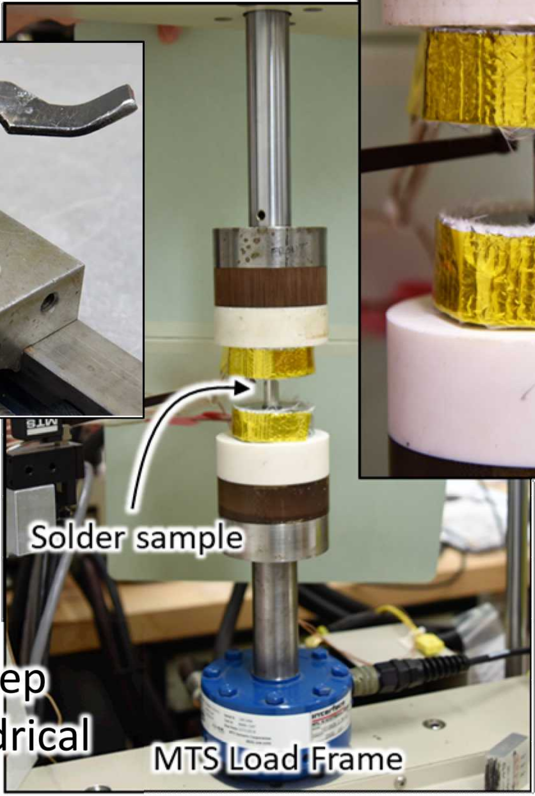


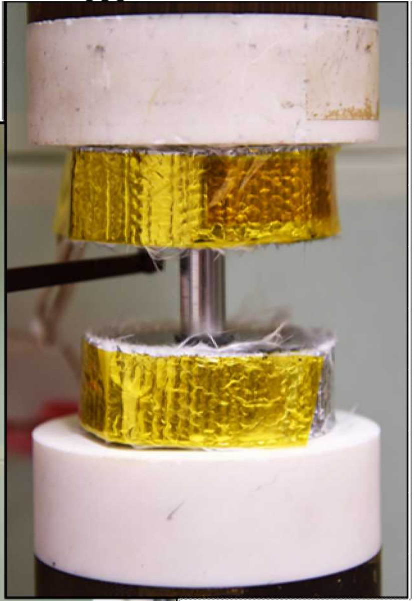
$d\gamma/dt = f(\sigma, T, E)$

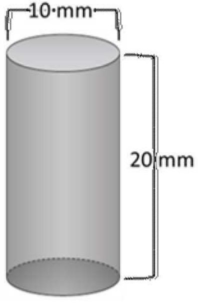
- σ, stress matrix
- T, temperature
- Elastic and physical properties

Test Set-up

Bullet mold immediately after molten solder was poured (left) and after rotating the mold top (right).

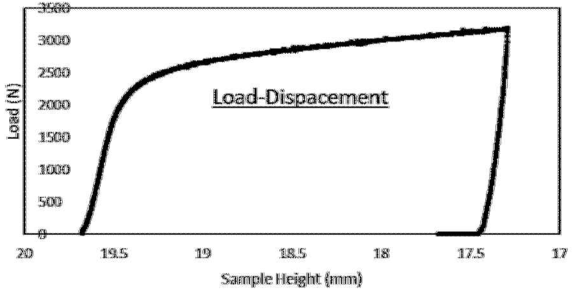


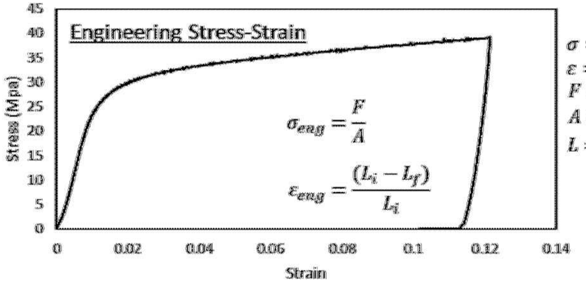




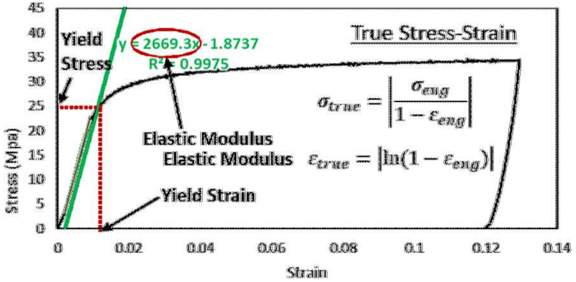
Test frame set-up for stress-strain and creep compression tests and schematic of cylindrical solder sample with nominal dimensions.

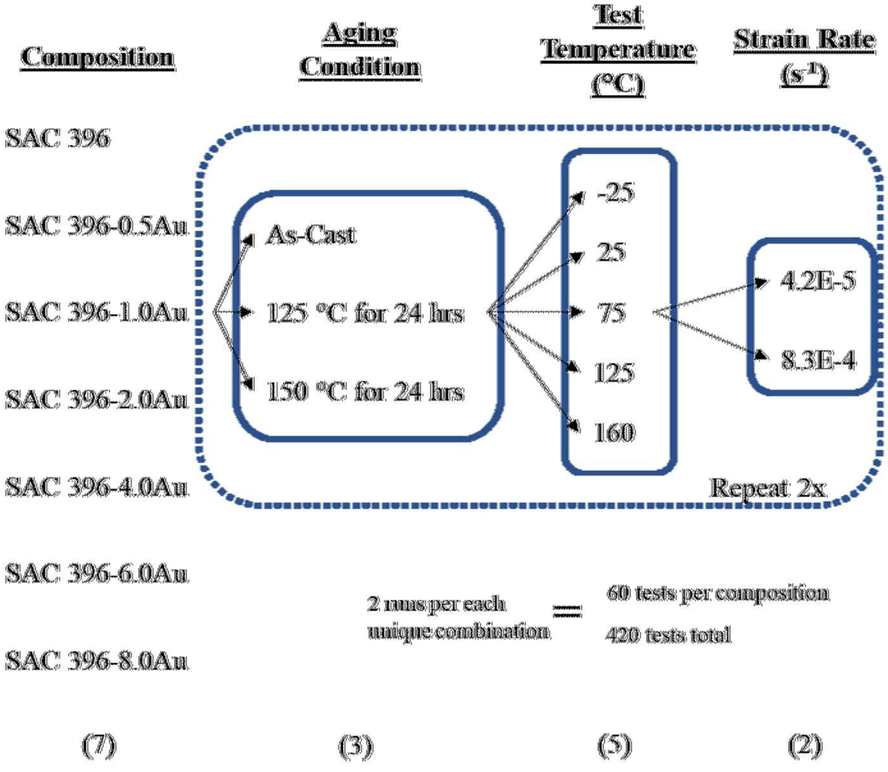
Stress-Strain Testing





$\sigma = stress$
$\varepsilon = strain$
$F = applied\ load\ (N)$
$A = cross\ sectional\ area\ (mm^2)$
$L = length (mm)$





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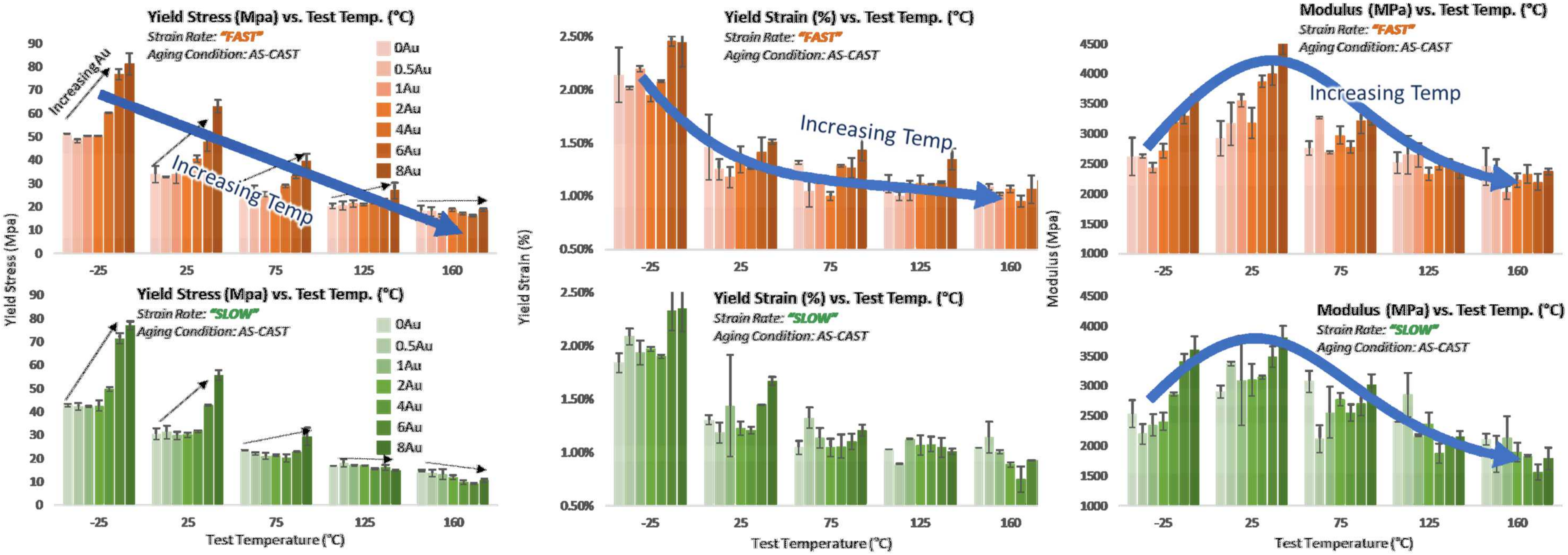

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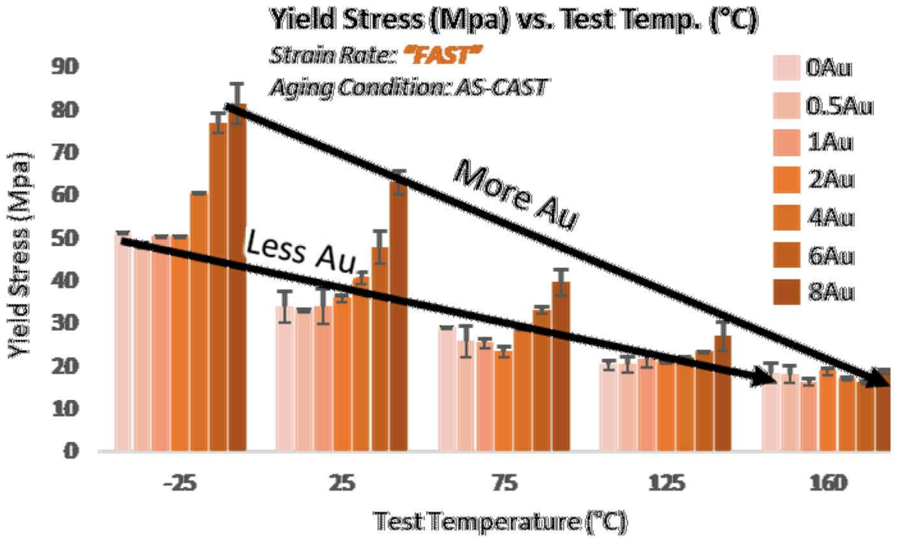
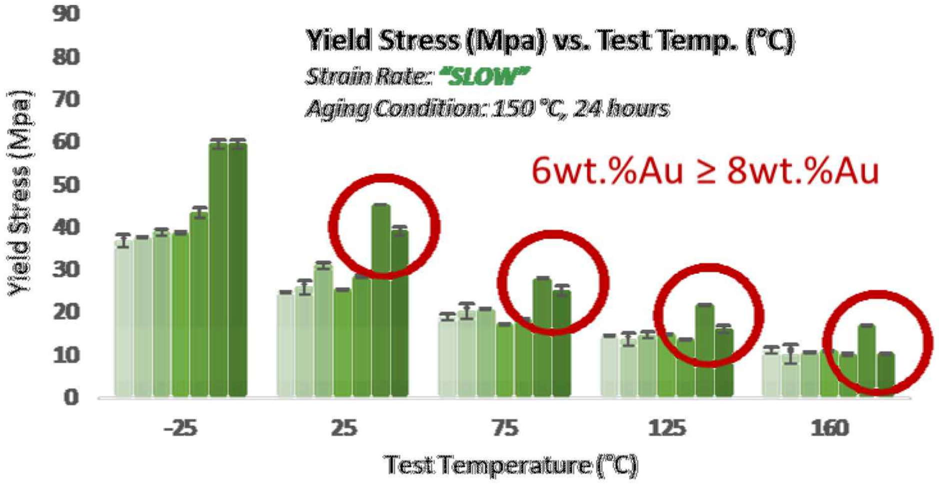
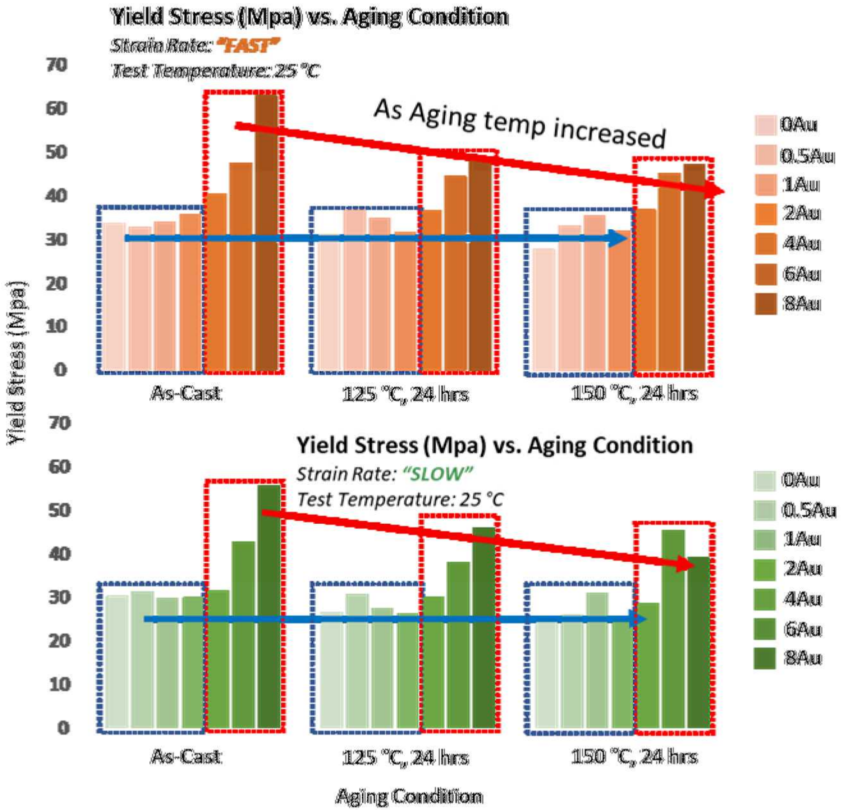
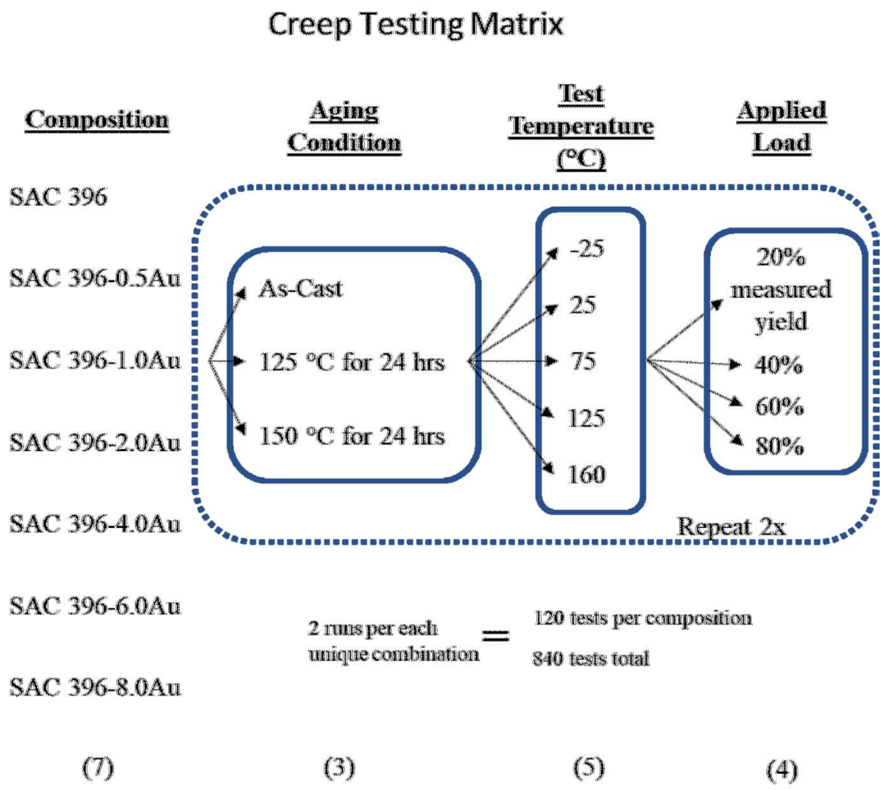


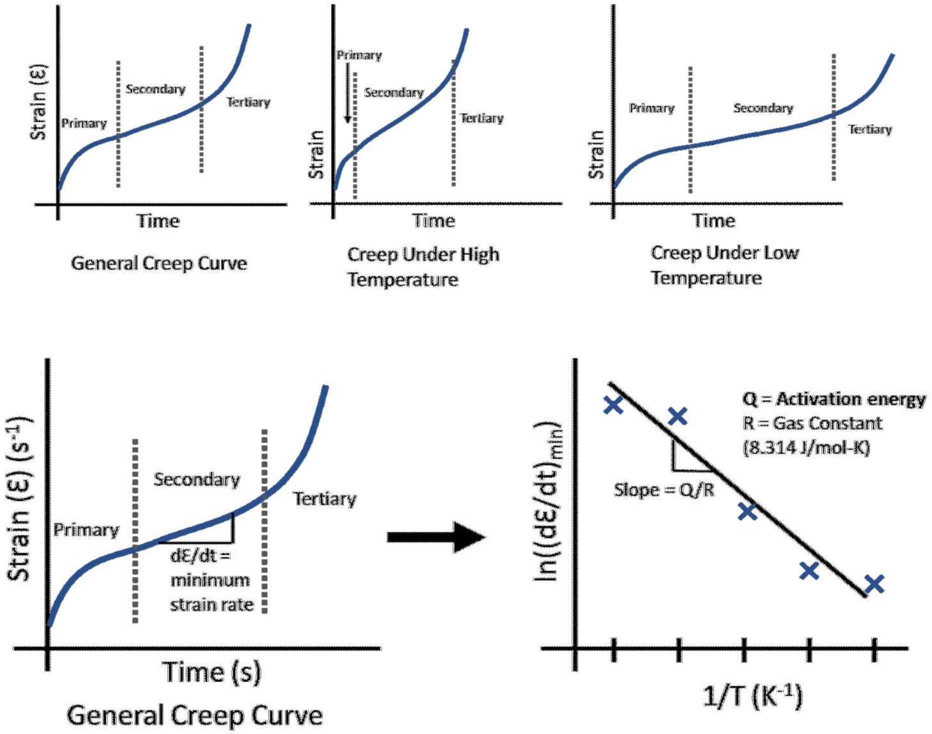


Stress-Strain Testing



Creep Testing





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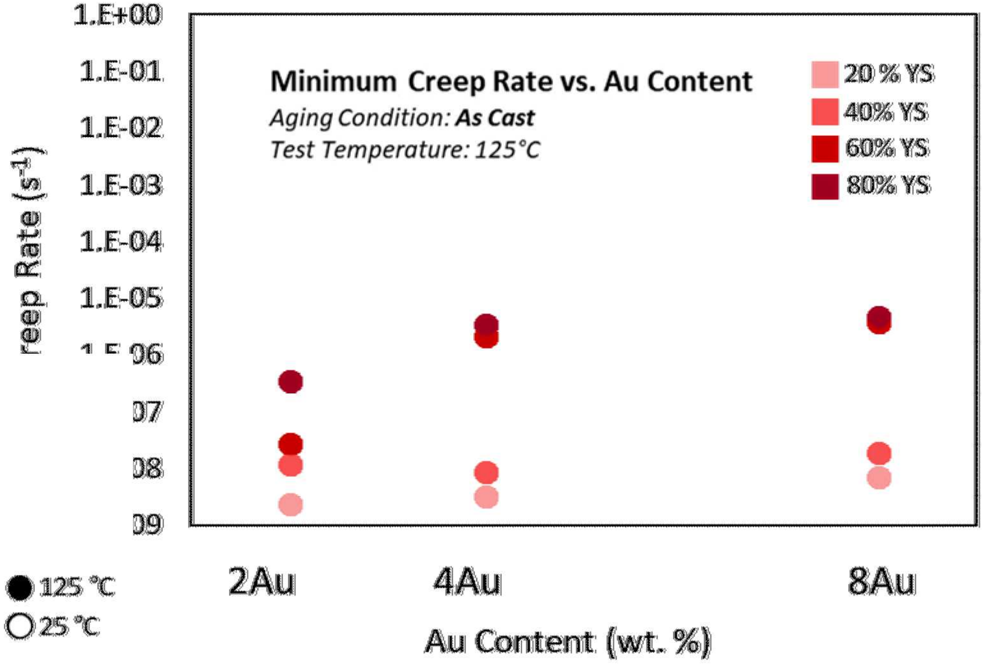
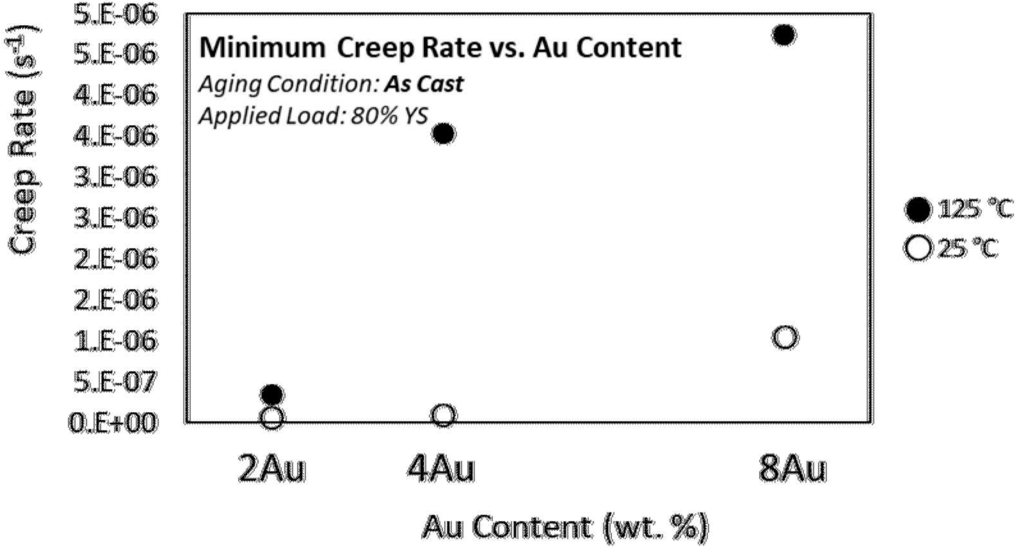
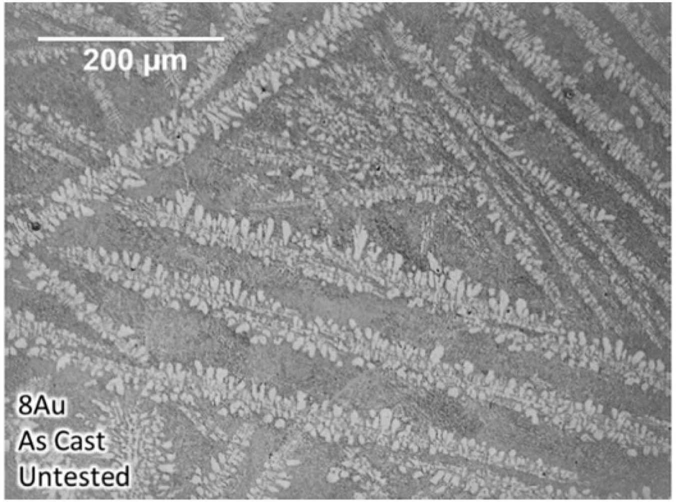
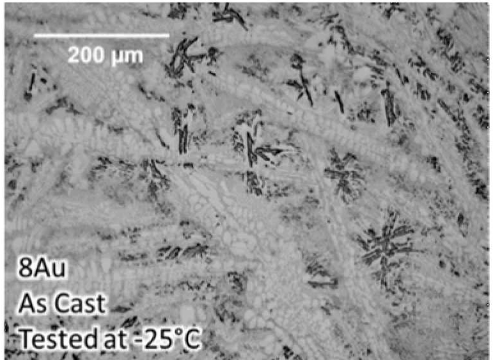
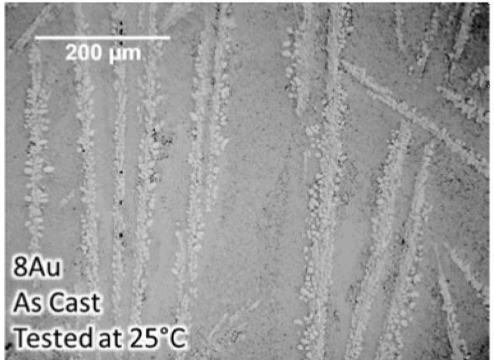


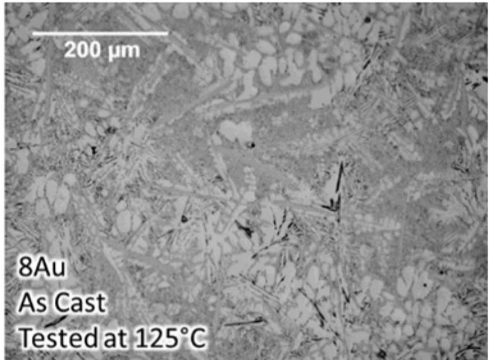


Metallography









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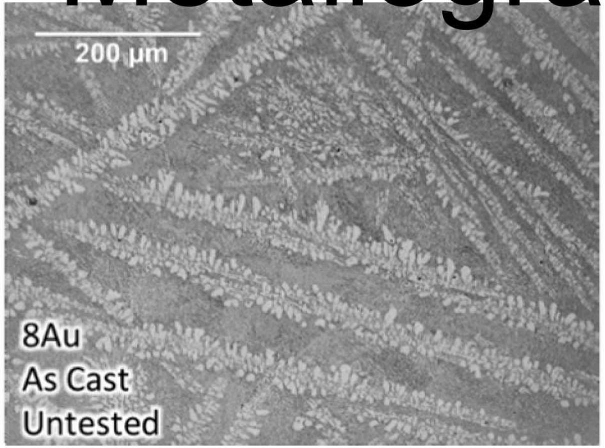

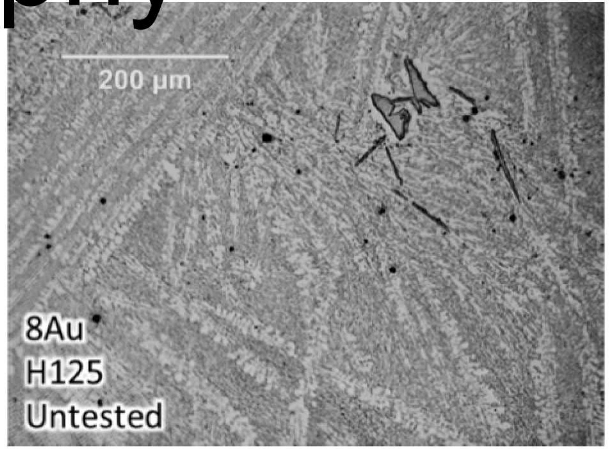

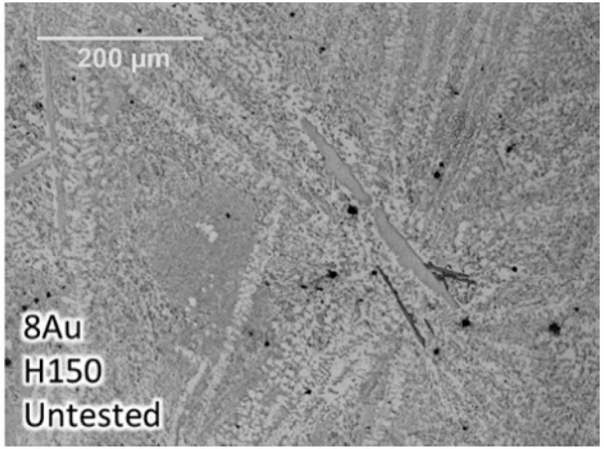

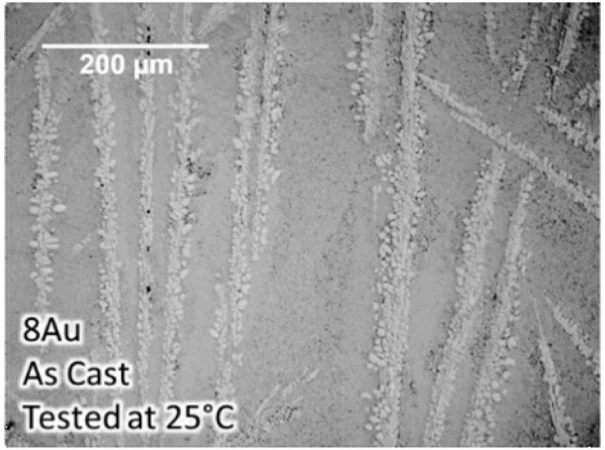

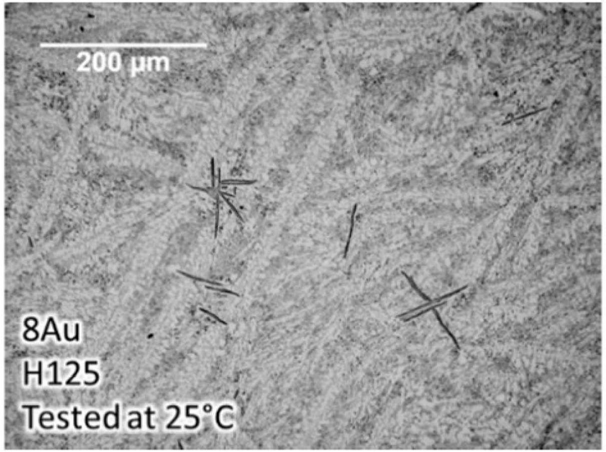

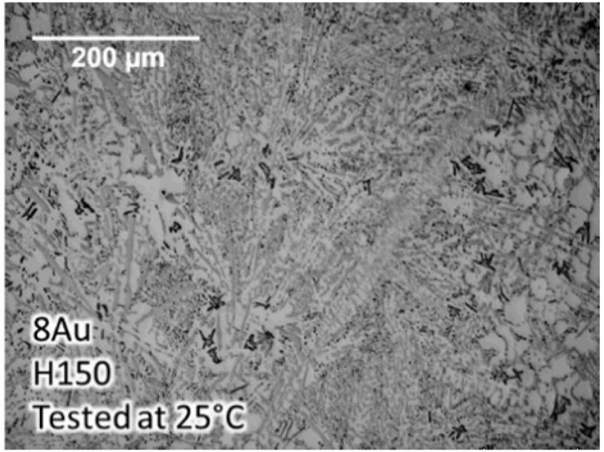

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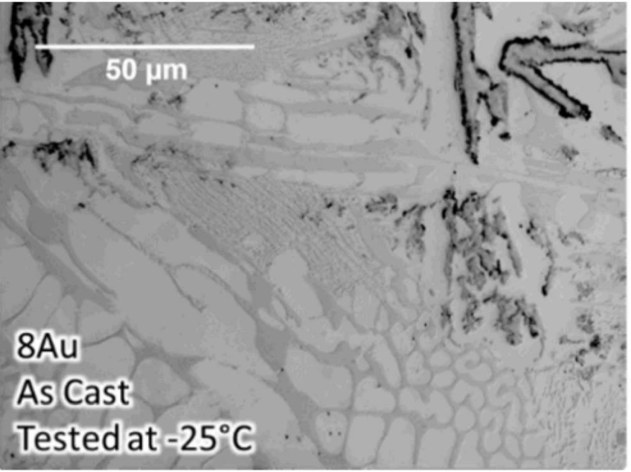
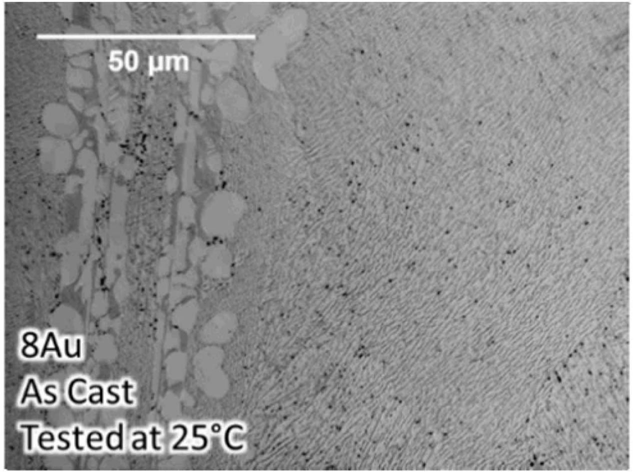
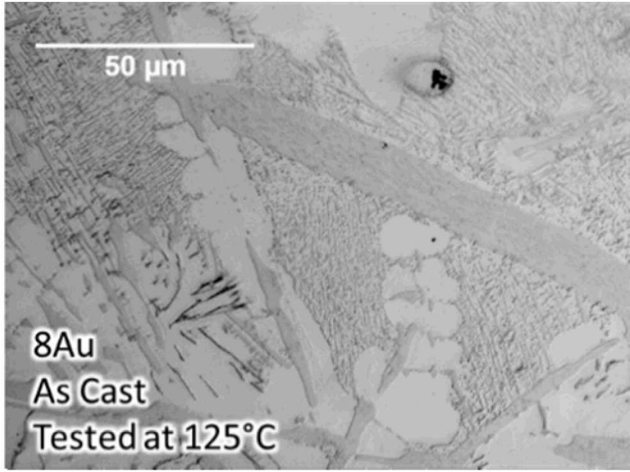
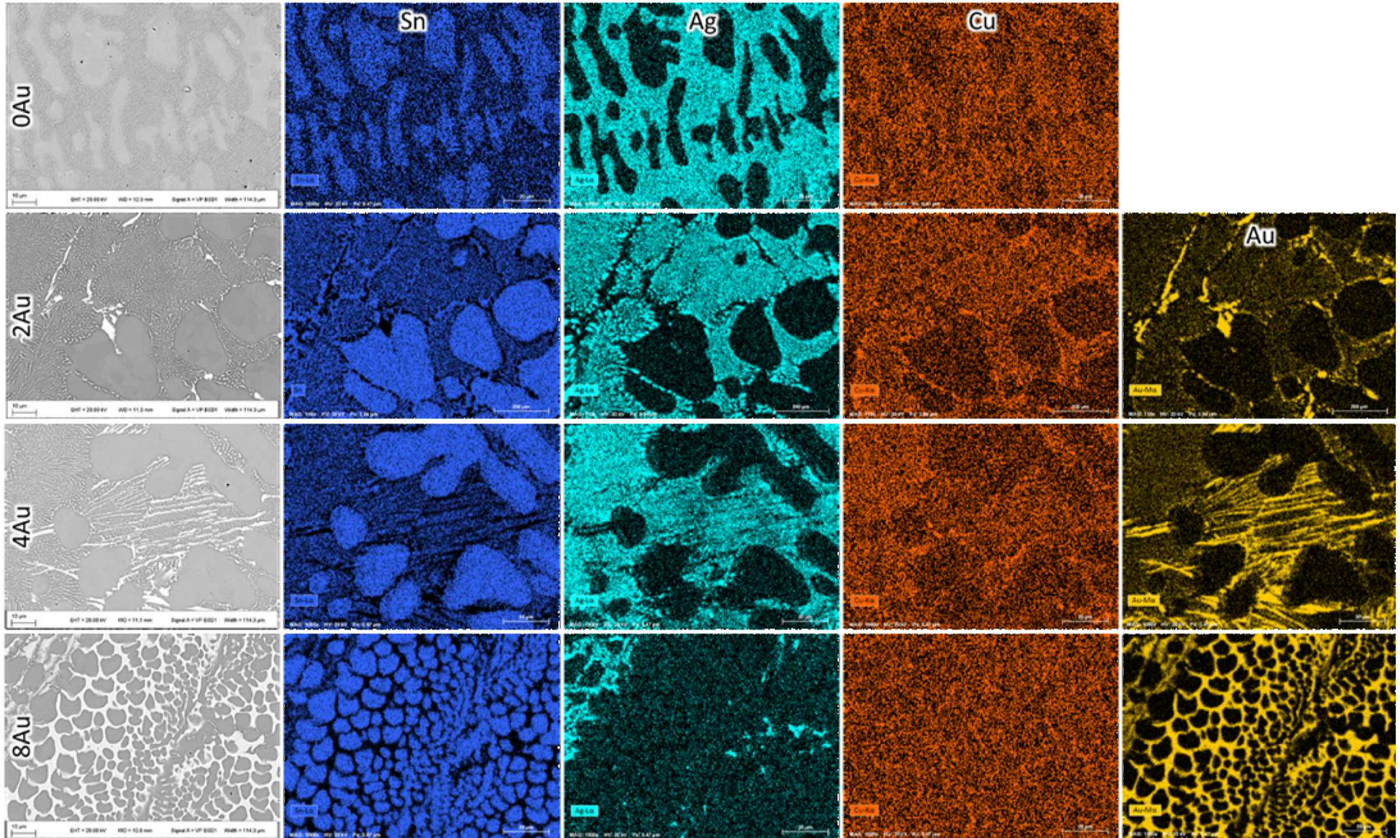






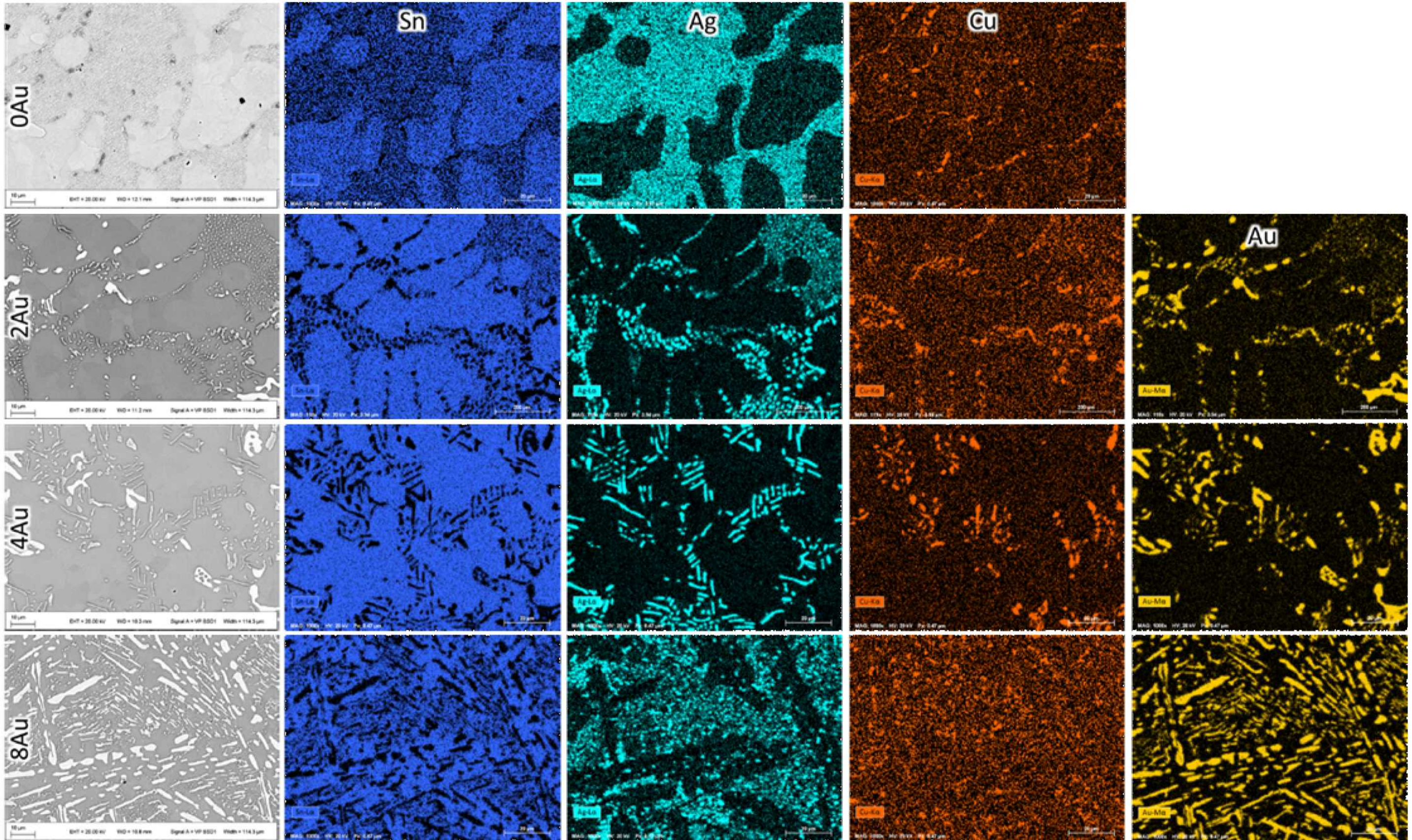
Metallography (Untested)

AS CAST



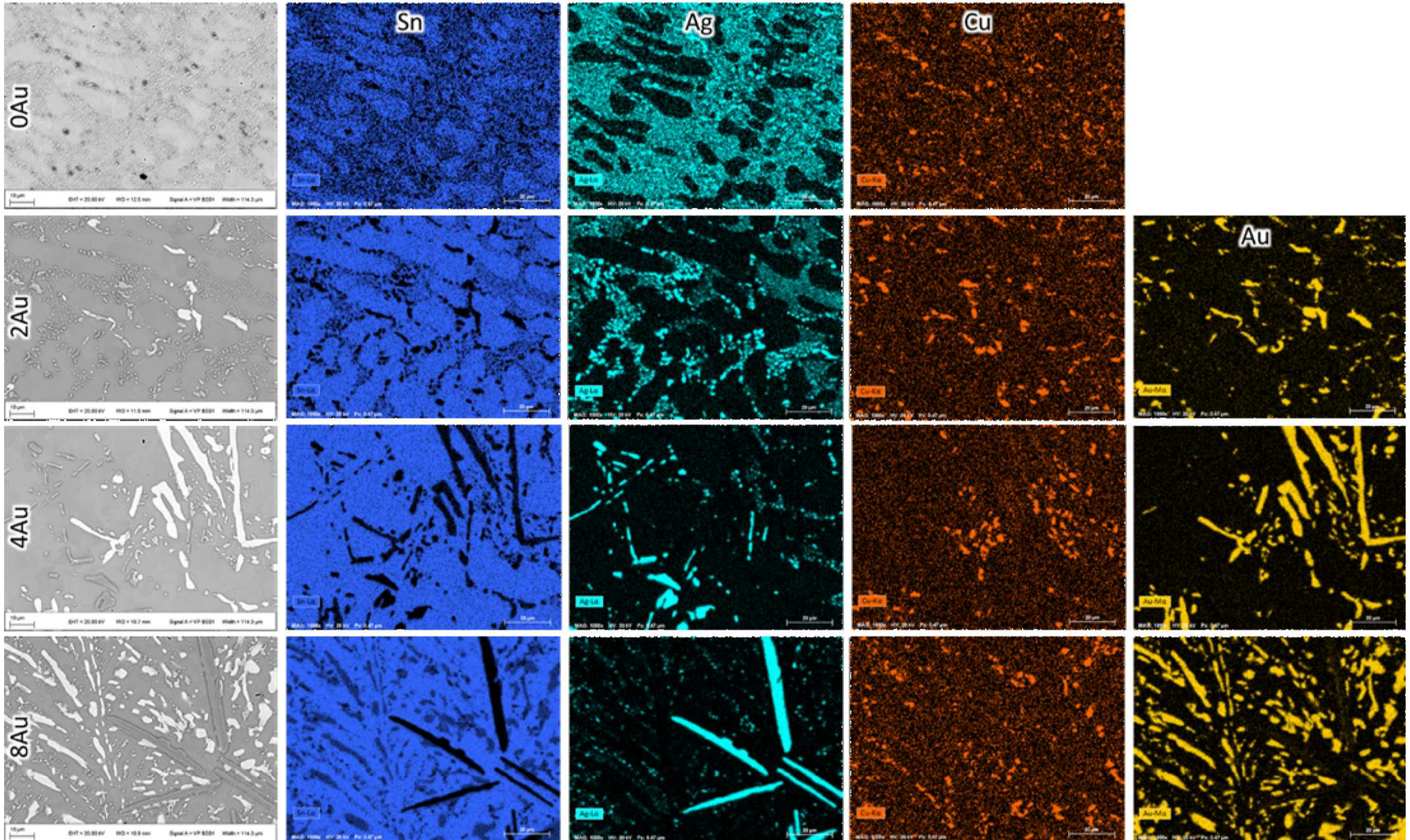
Metallography (Untested)

Aged 24 hrs, 125°C



Metallography (Untested)

Aged 24 hrs, 150°C

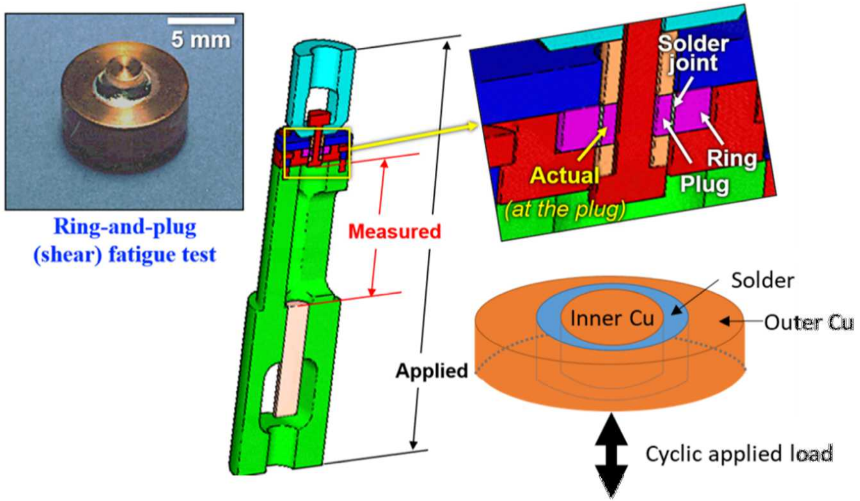


Conclusions

- Stress-strain compression testing is complete
  - Test temperature and Au content indirectly relate to Y.S.
- Stress-strain creep testing is in progress
  - Creep rates are directly related to test temperature, Au content, and applied load
- More results will be available at the time of the conference

Future Outlook

- High cycle fatigue studies
  - Sample prep is completed
- Advanced characterization
- Creep, creep, creep…



Thank You!

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