OAK RIDGE National Laboratory

DOE Transformational Challenge Reactor Program

US NRC Workshop on Advanced Manufacturing Technologies for Nuclear Applications

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Director – Transformational Challenge Reactor

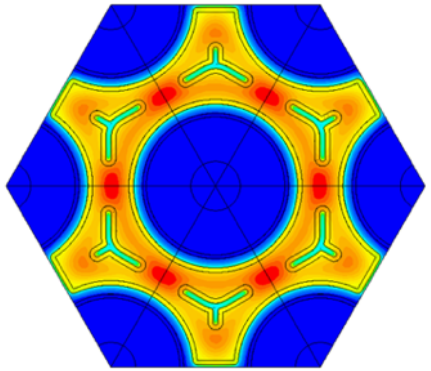
December 10, 2020

ORNL is managed by UT-Battelle, LLC for the US Department of Energy

U.S. DEPARTMENT OF ENERGY

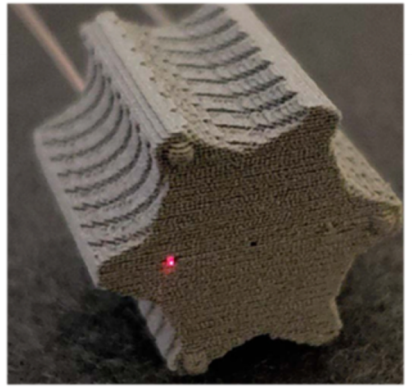
TCR is bringing to bear additive manufacturing (AM) and artificial intelligence (AI) to deliver a new approach

Using AI to navigate an unconstrained design space and realize superior performance

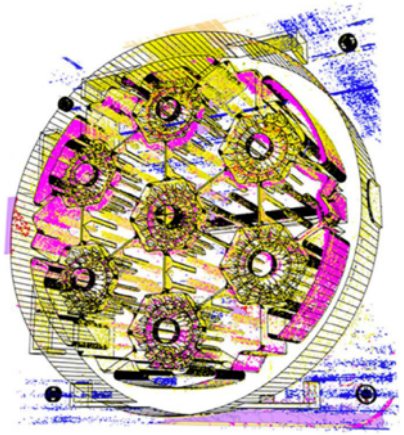


Leveraging AM to arrive at high-performance materials in complex geometries

Exploiting AM to incorporate integrated and distributed sensing in critical locations



Using AI to assess critical component quality using in situ manufacturing signatures



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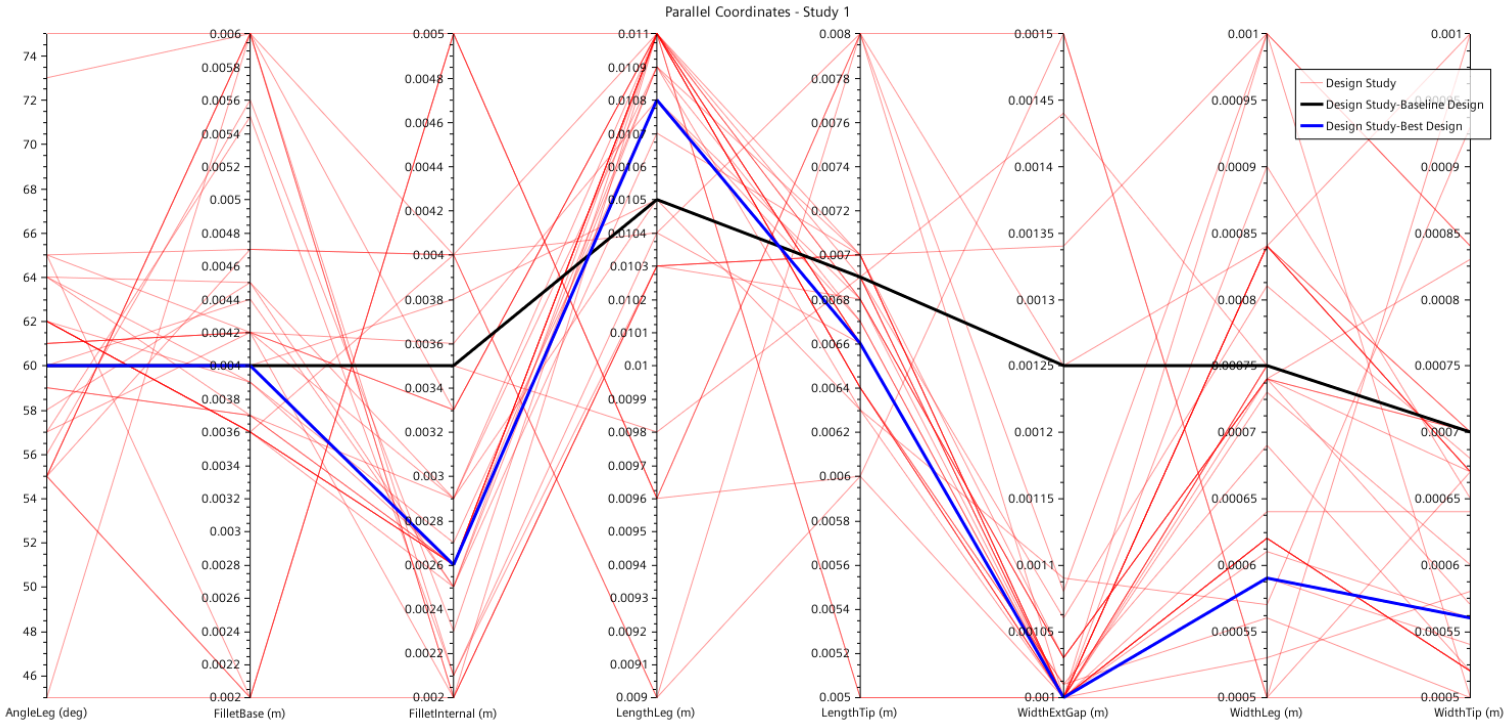
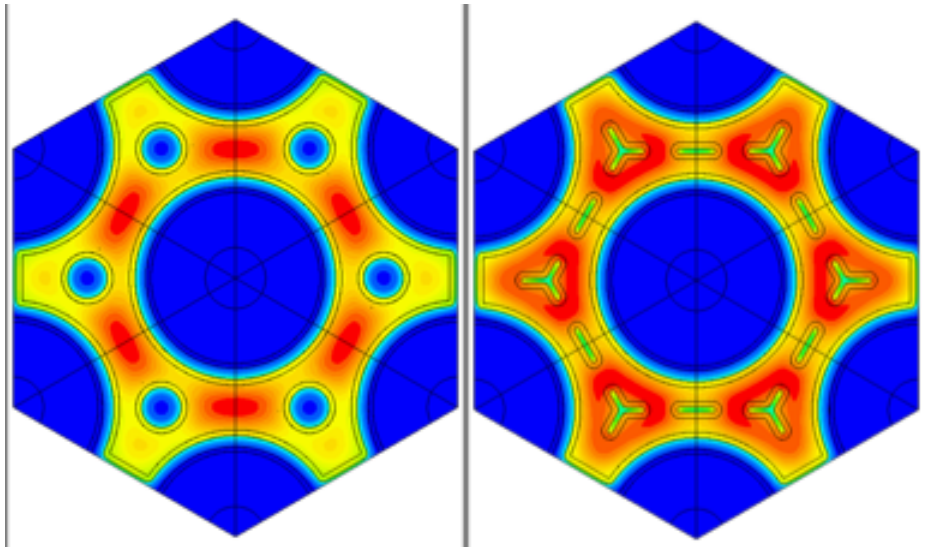
Navigating the unconstrained deigns space offered by AM presents performance opportunities

parameter space search to find optimized cooling channel design

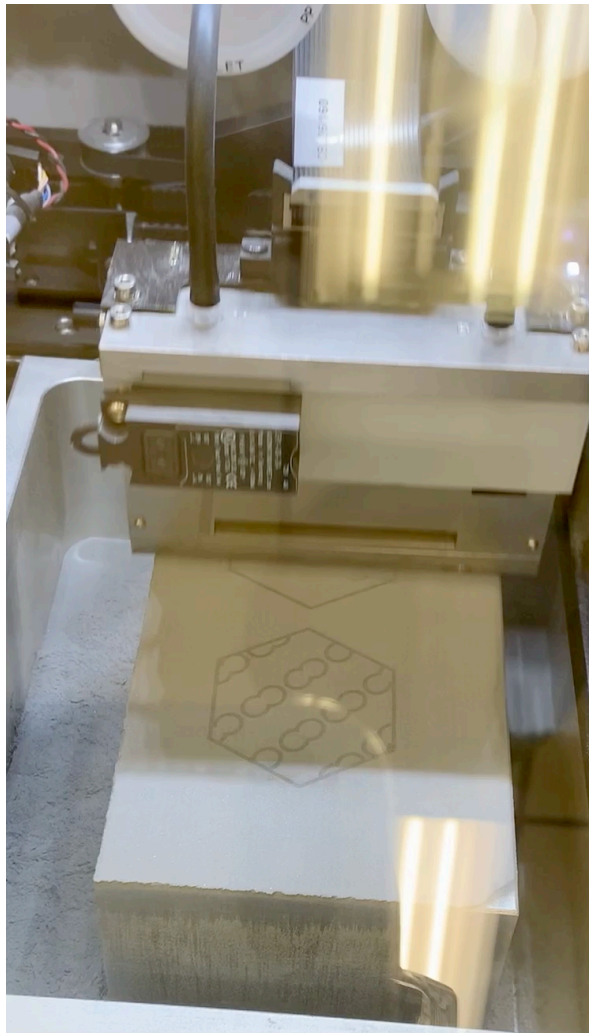




Tmax = 687 C, ΔT = 119 C
Core ΔP = 0.56 psi

Tmax = 622 C, ΔT = 78 C
Core ΔP = 1 psi

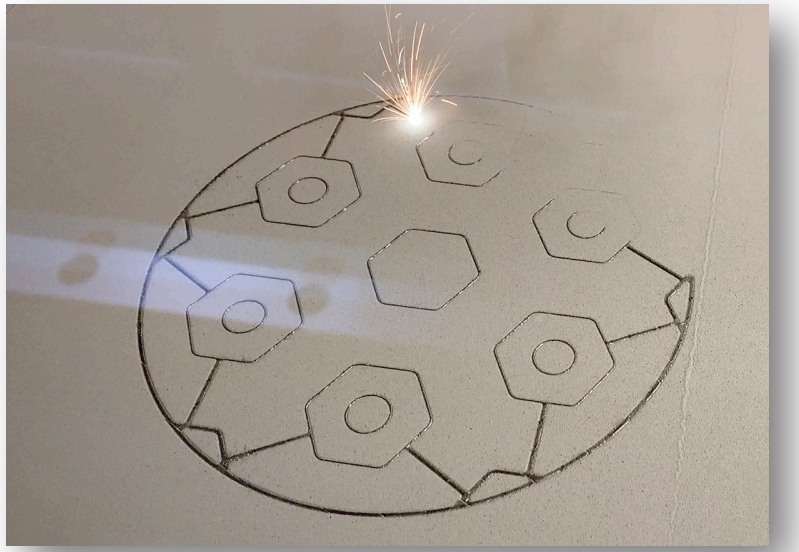
Leveraging AM to arrive at high-performance radiation tolerant ceramic materials in complex geometries

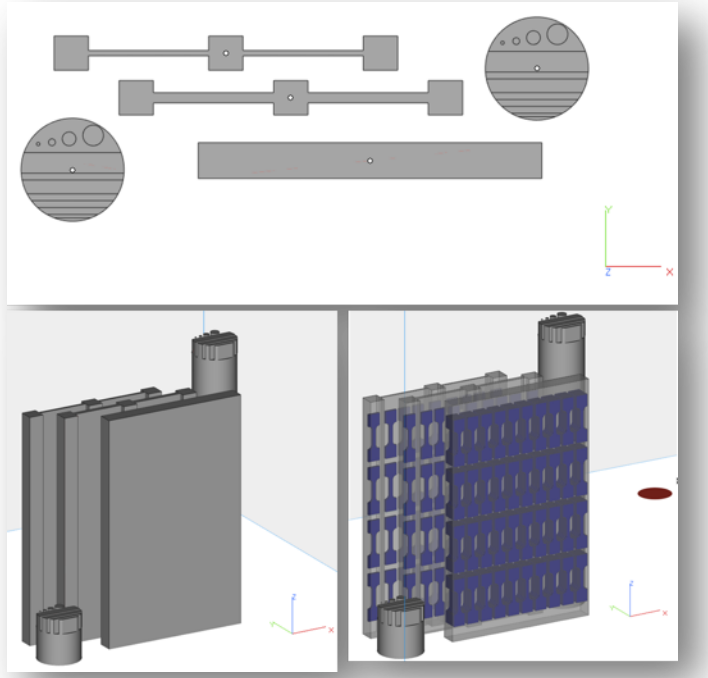


computer-aided design 3D printed shell

fully densified

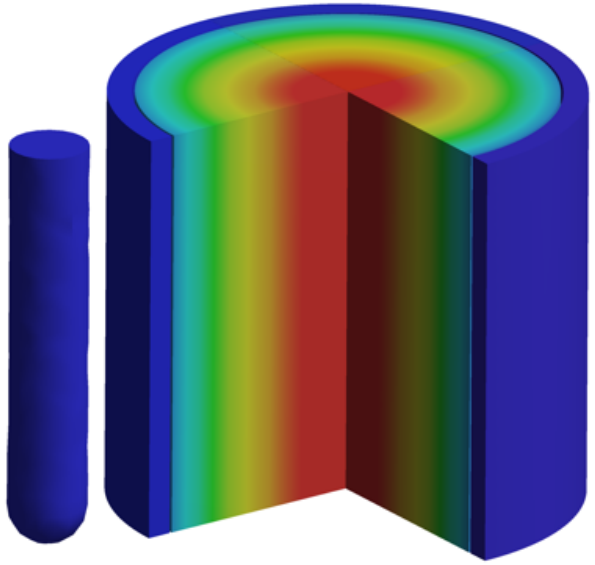
Codification of metal additive manufacturing with a focus on powder bed methodologies was pursued in 2020





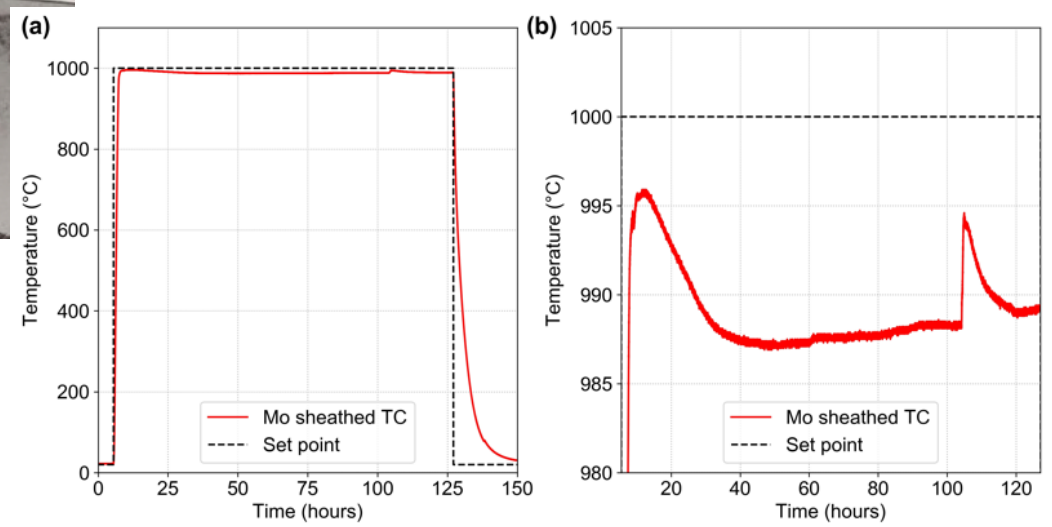
Incorporating sensors into critical structure via AM to harvest operational data and facilitate health monitoring

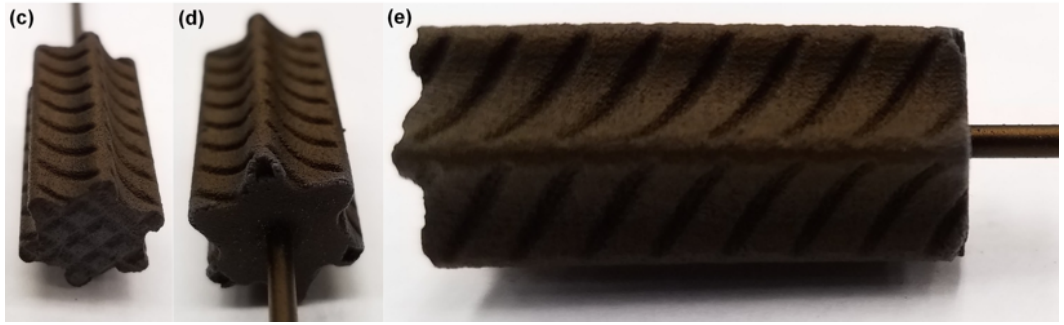
Conventional instrumentation



Embedded sensor sheathes in additively manufactured stainless steel and silicon carbide

Integrated instrumentation





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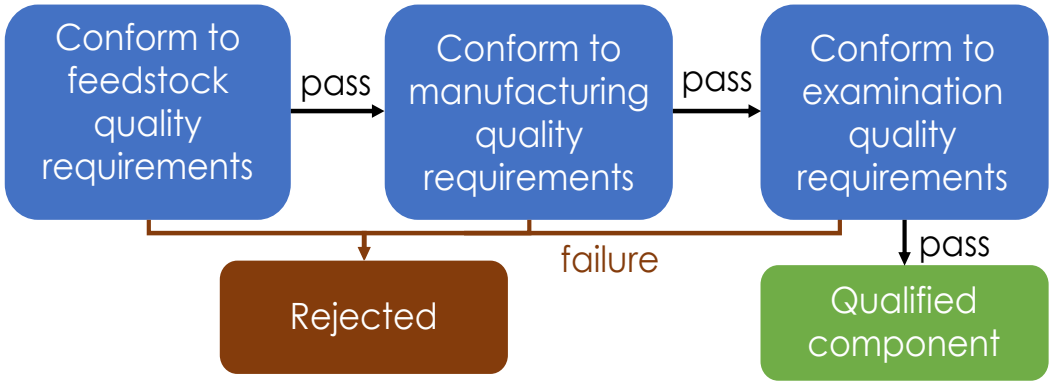
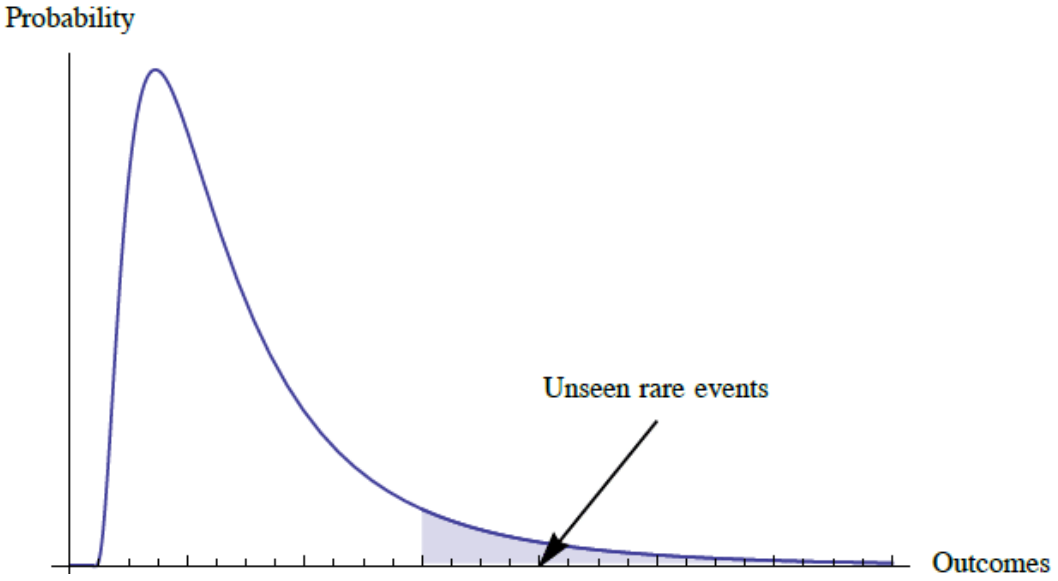
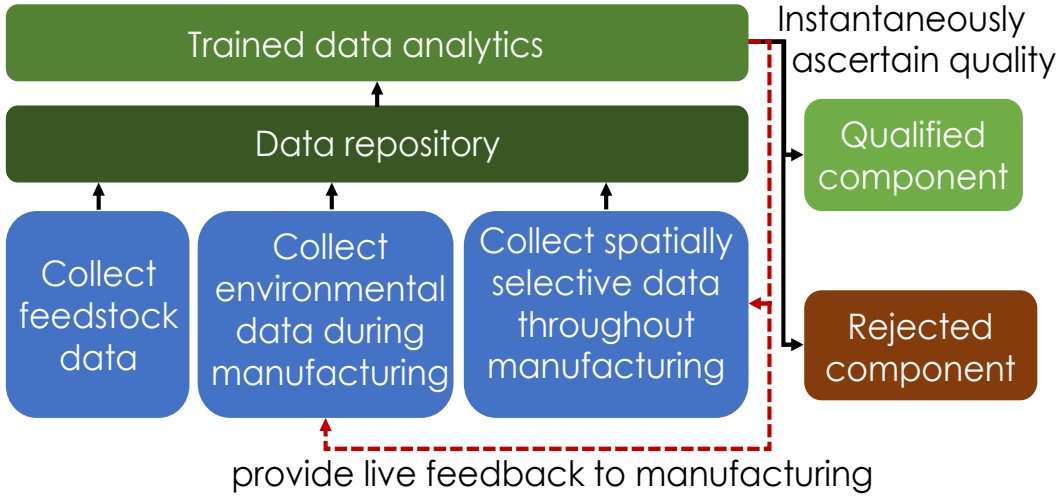
Applying the current approach for quality certification of critical components derived via AM is procrustean







rapid iteration

Digital Thread

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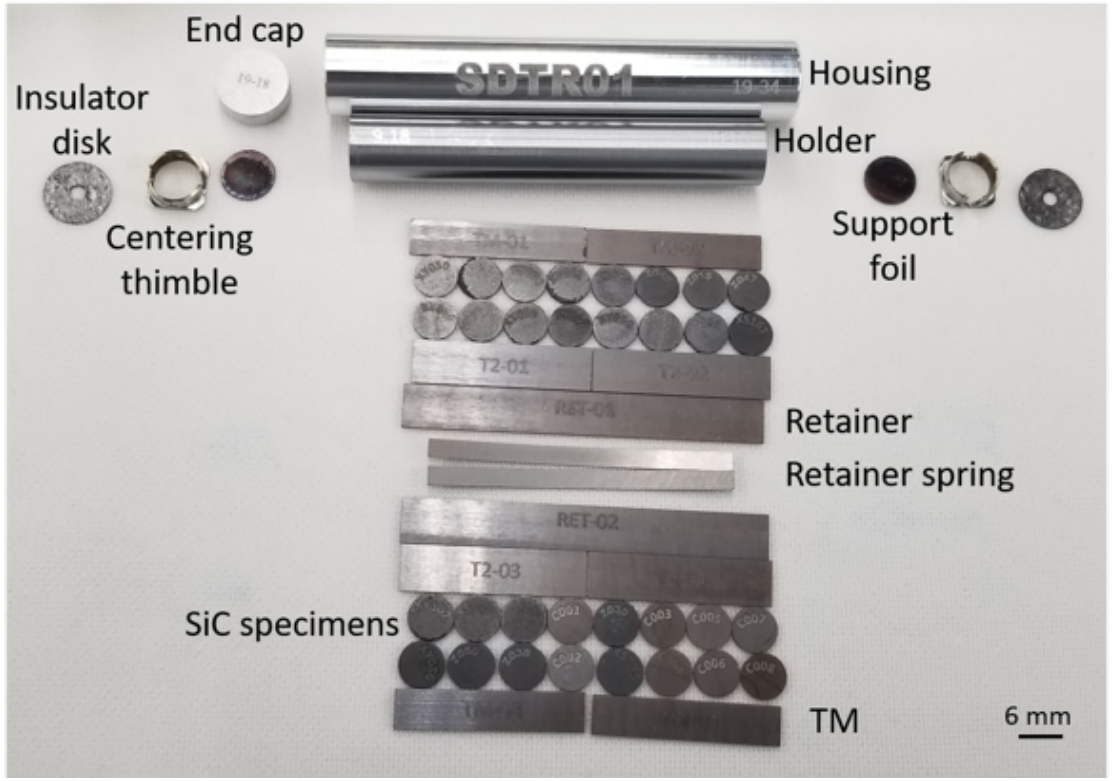
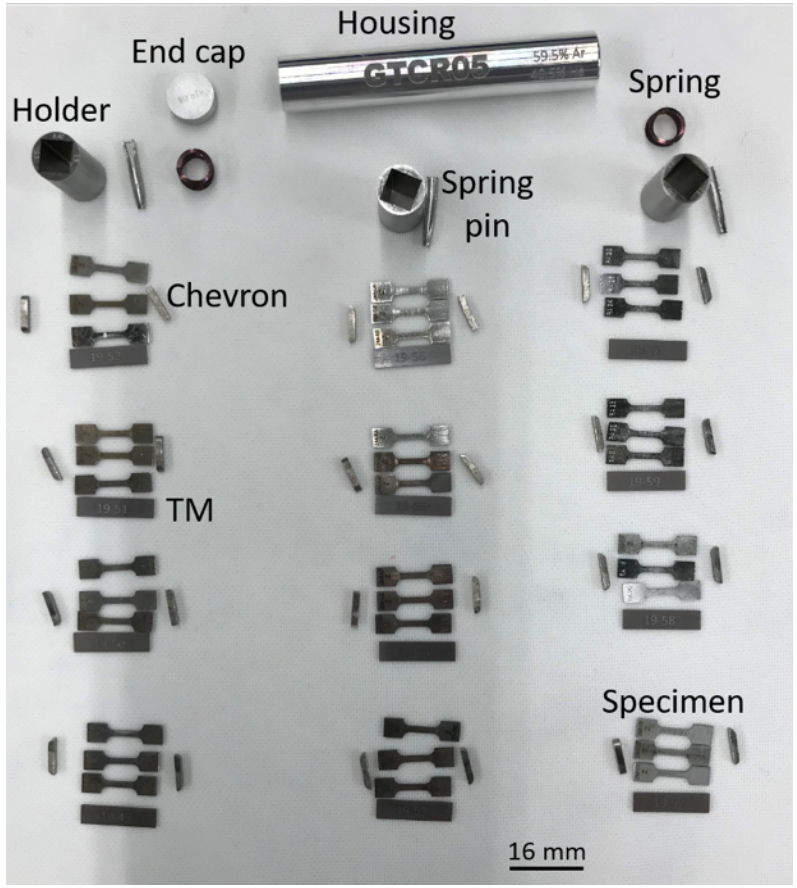
Extensive testing, including exposure to displacement damage inducing neutrons, are a core part of TCR

Typical HFIR irradiation capsule for ceramics

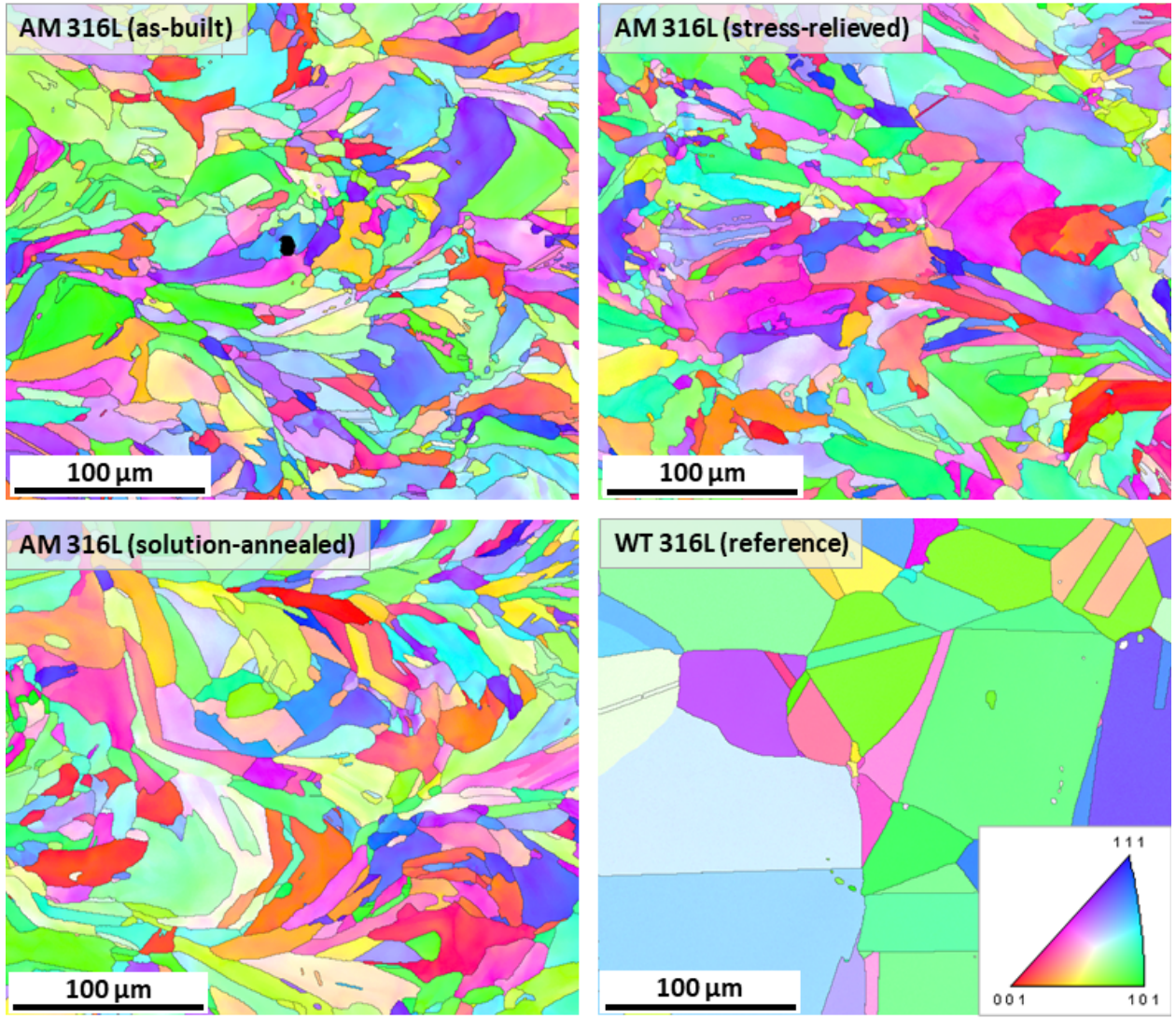


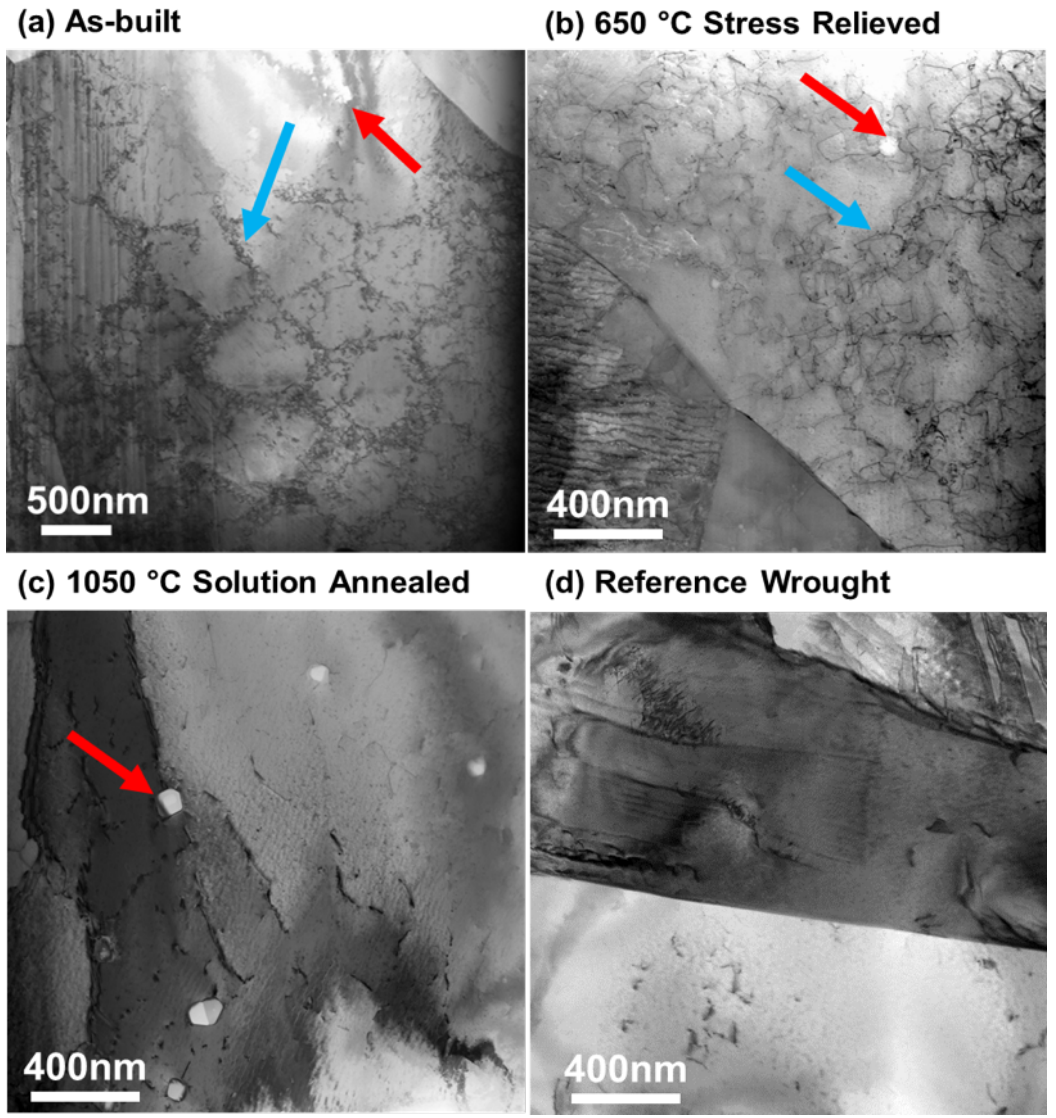
Typical HFIR irradiation capsule for metals



Roughly 25 capsules irradiated in 2020: SiC, YHx, 316L, Inc 718

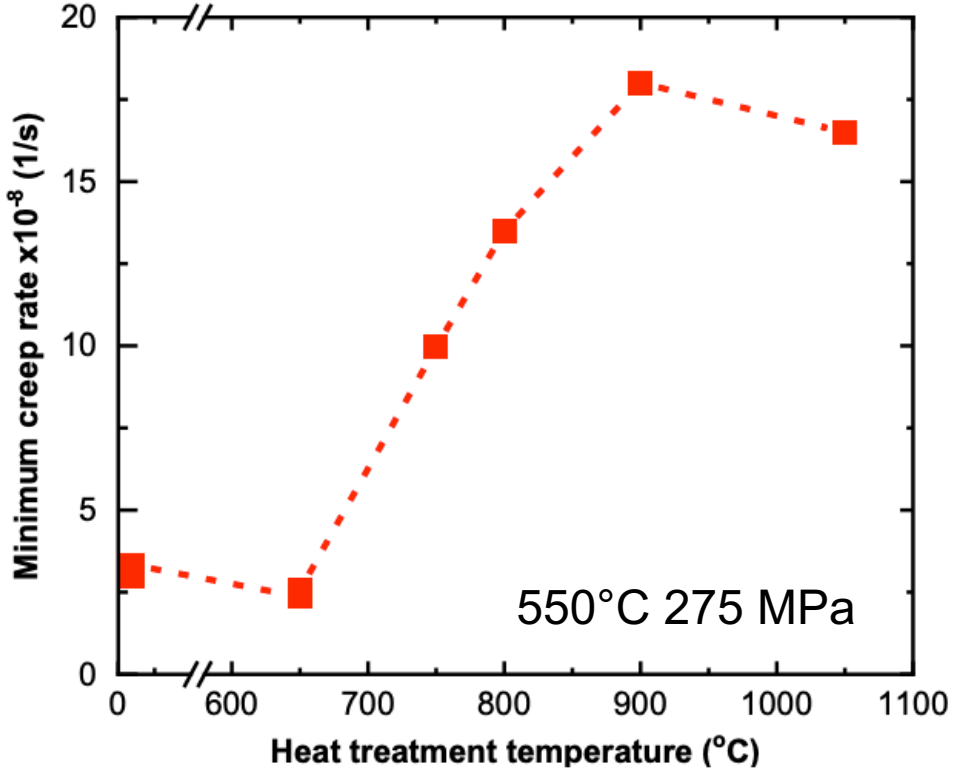
316L microstructure after additive manufacturing and prior to irradiation

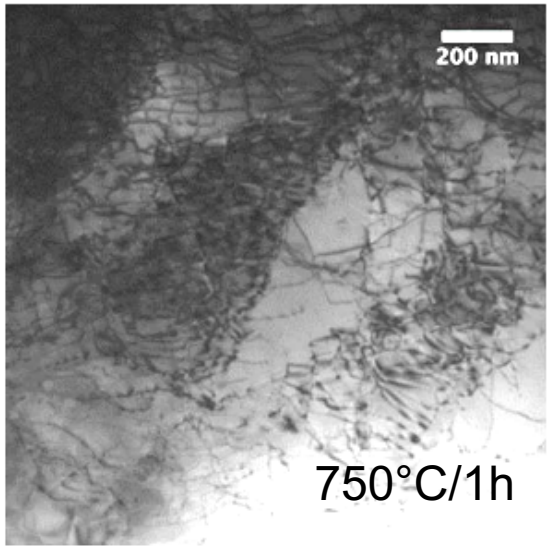


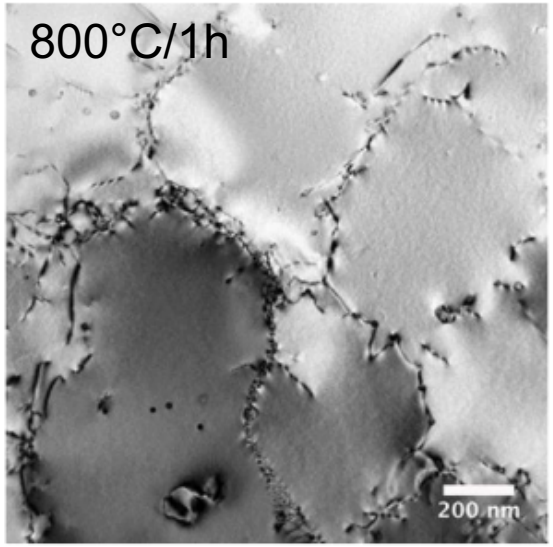


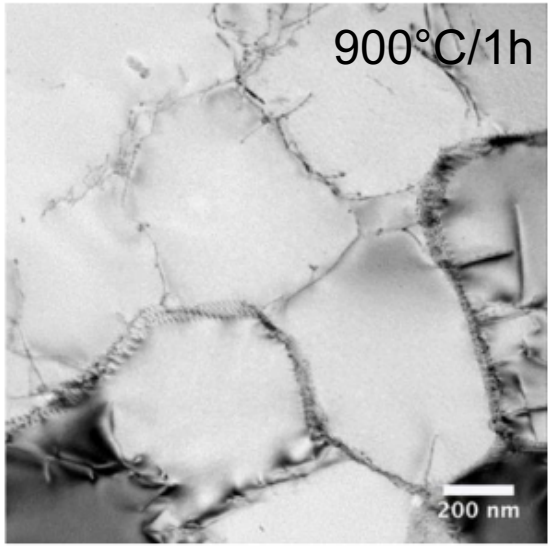
(M. Gussev, T. Lach, ORNL)

The dislocation cells in AM 316L are tenacious, affect creep behavior of the material, and only disappear above 950°C



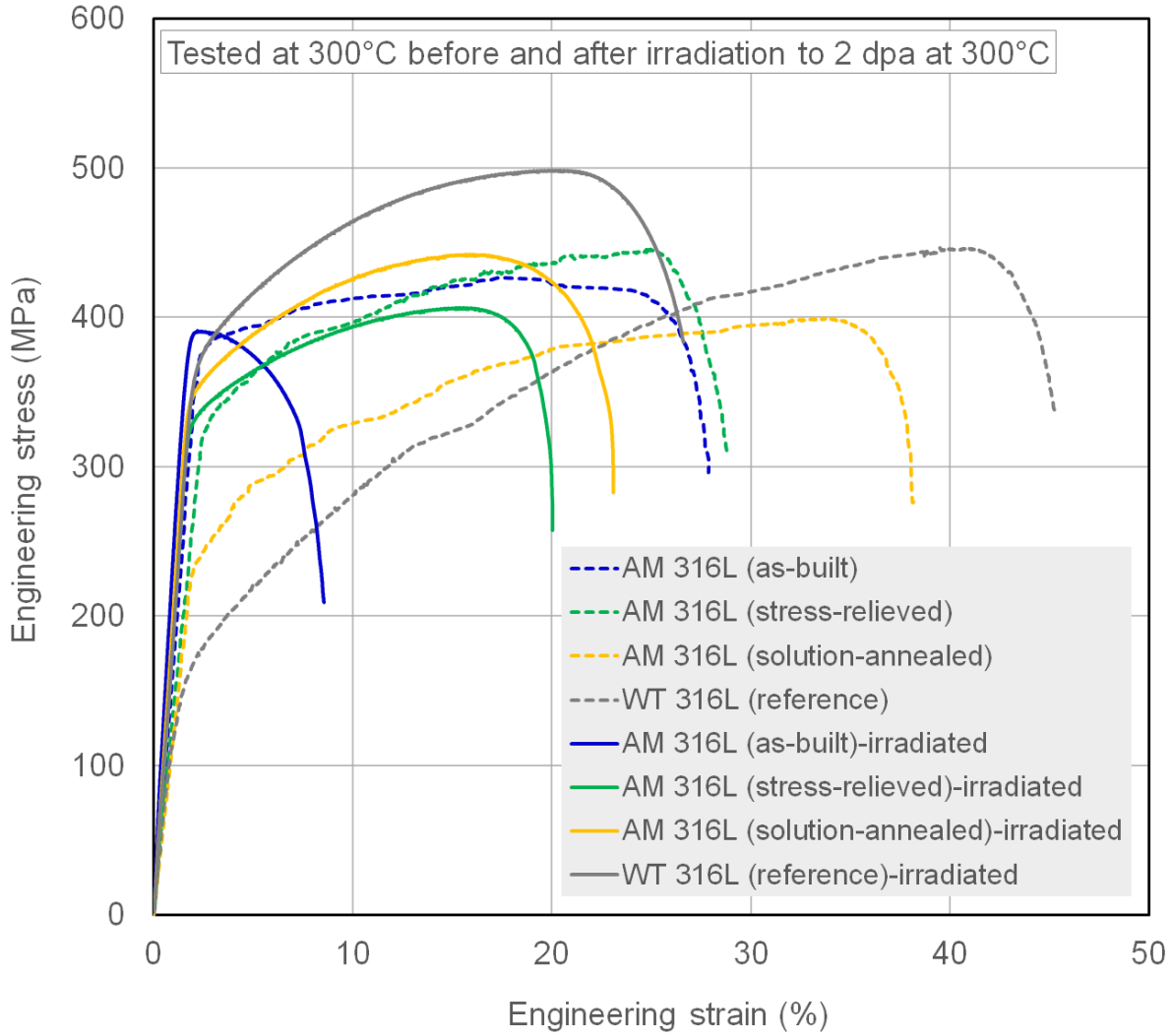


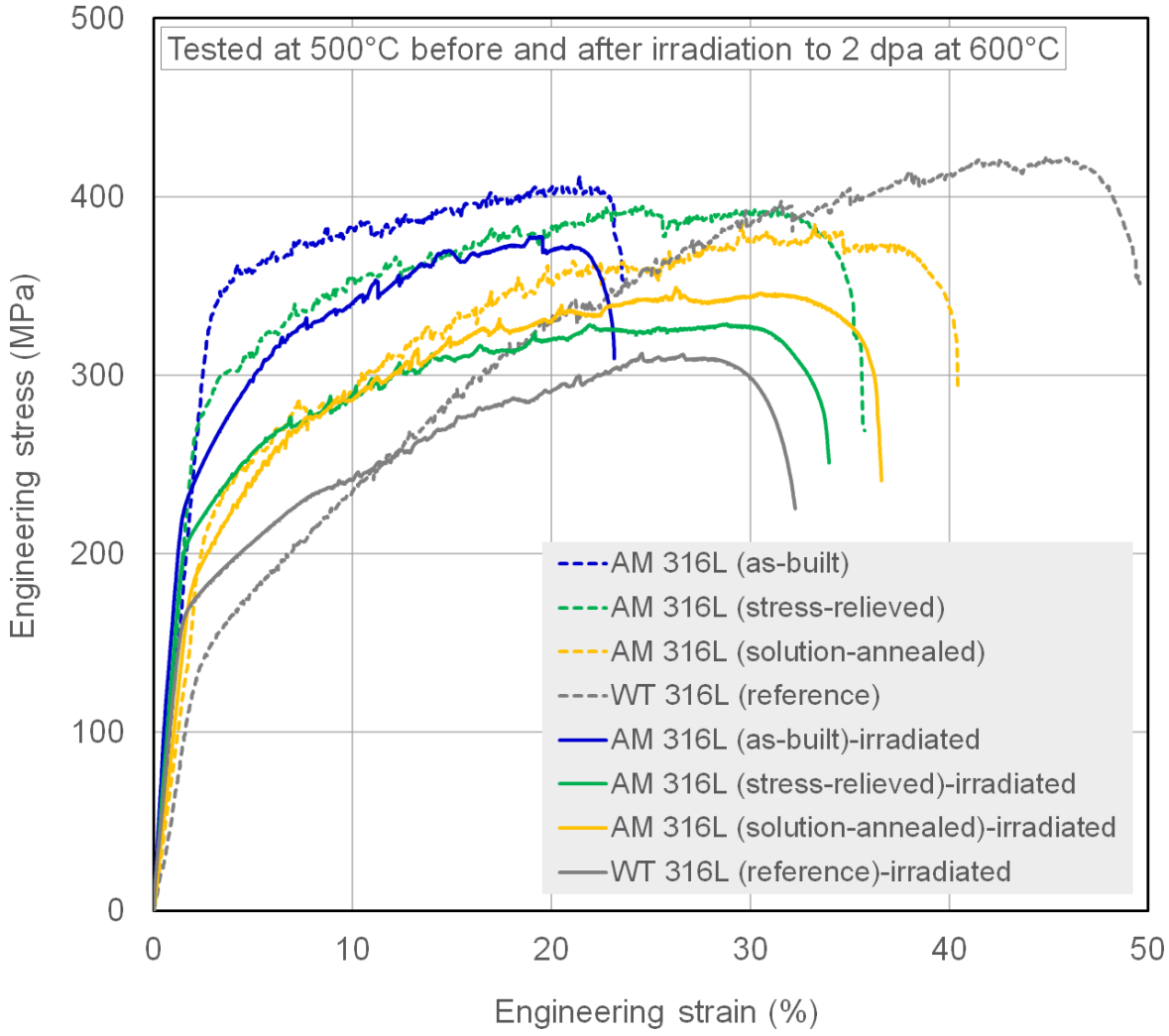




(M. Li, ANL)

Evolution of the dislocations in the AM, annealed, and wrought 316L govern their response under deformation





T.S. Byun, ORNL)

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Concluding Thoughts

- TCR aims to harness advanced in manufacturing and computational science to deliver materials and components for advanced nuclear energy systems
- The goal is to develop and demonstrate high TRL to facilitate industrial adoption

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