INL/MIS-25-86290-Revision-0

Gen IV International Forum Interactions

July 2025

William Corwinn

Changing the World's Energy Future

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July 2025

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GAS-COOLED REACTOR
ADVANCED REACTOR TECHNOLOGIES PROGRAM

GEN IV International Forum
Expertise | Collaboration | Excellence

Presentation ***Wednesday, July 30, 2025***

Gen IV International Forum Interactions

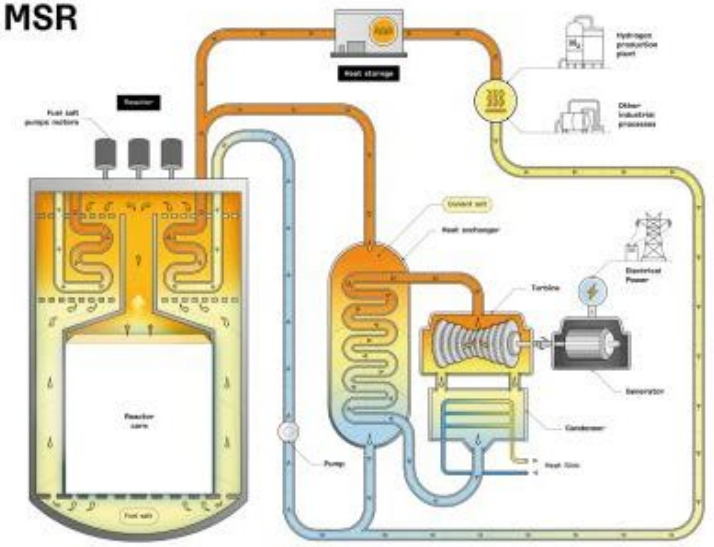
INL/MIS-25-86290

William Corwin
Co-Chair VHTR Materials PMB
President, Advanced Reactor Materials LLC

DOE ART GCR Review Meeting
Hybrid Meeting at INL
July 29–30, 2025

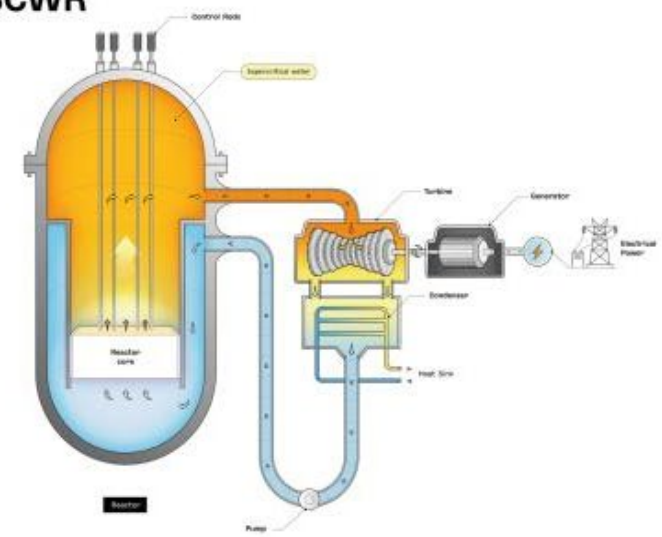
Gen IV Intl. Forum (GIF) Addresses 6 Advanced Hi-temp Reactor Systems

MSR



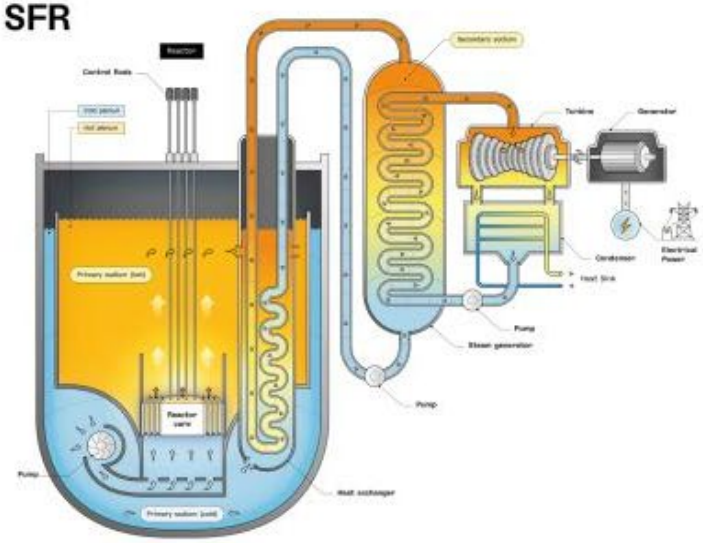
Molten Salt Reactor

SCWR



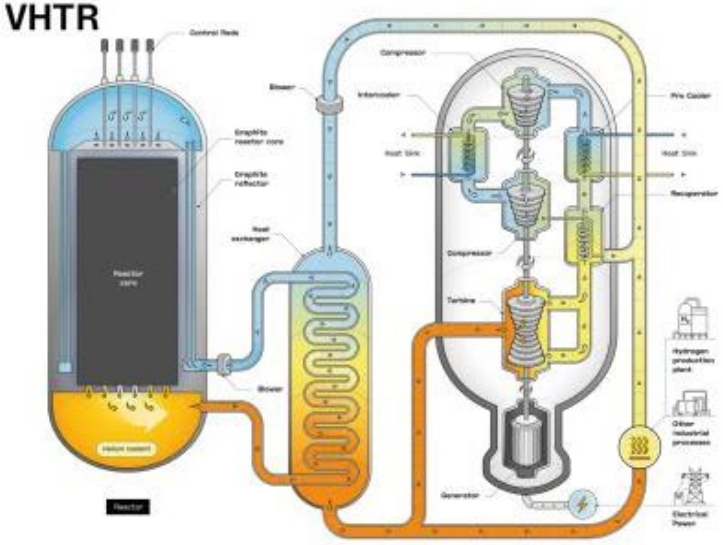
SuperCritical-Water-Cooled Reactor

SFR



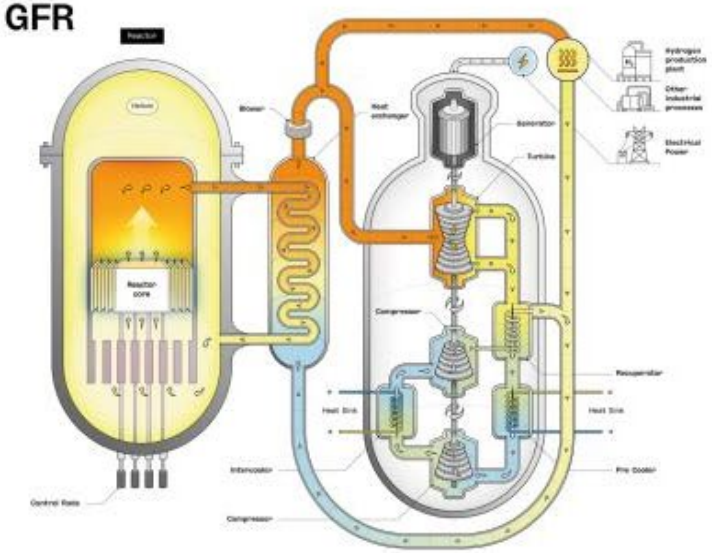
Sodium-cooled Fast Reactor

VHTR



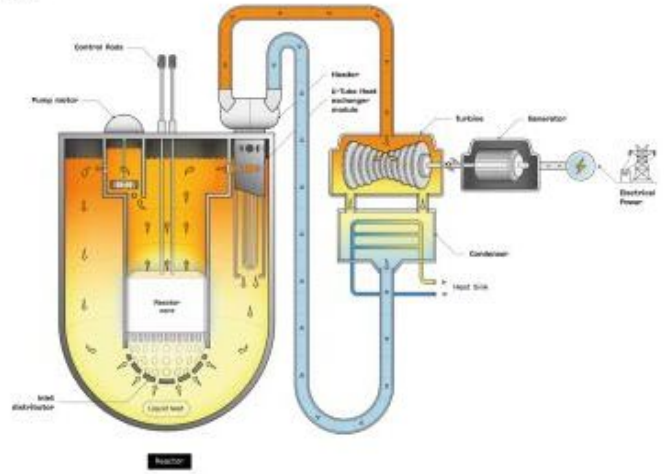
Very-High-Temperature Reactor

GFR

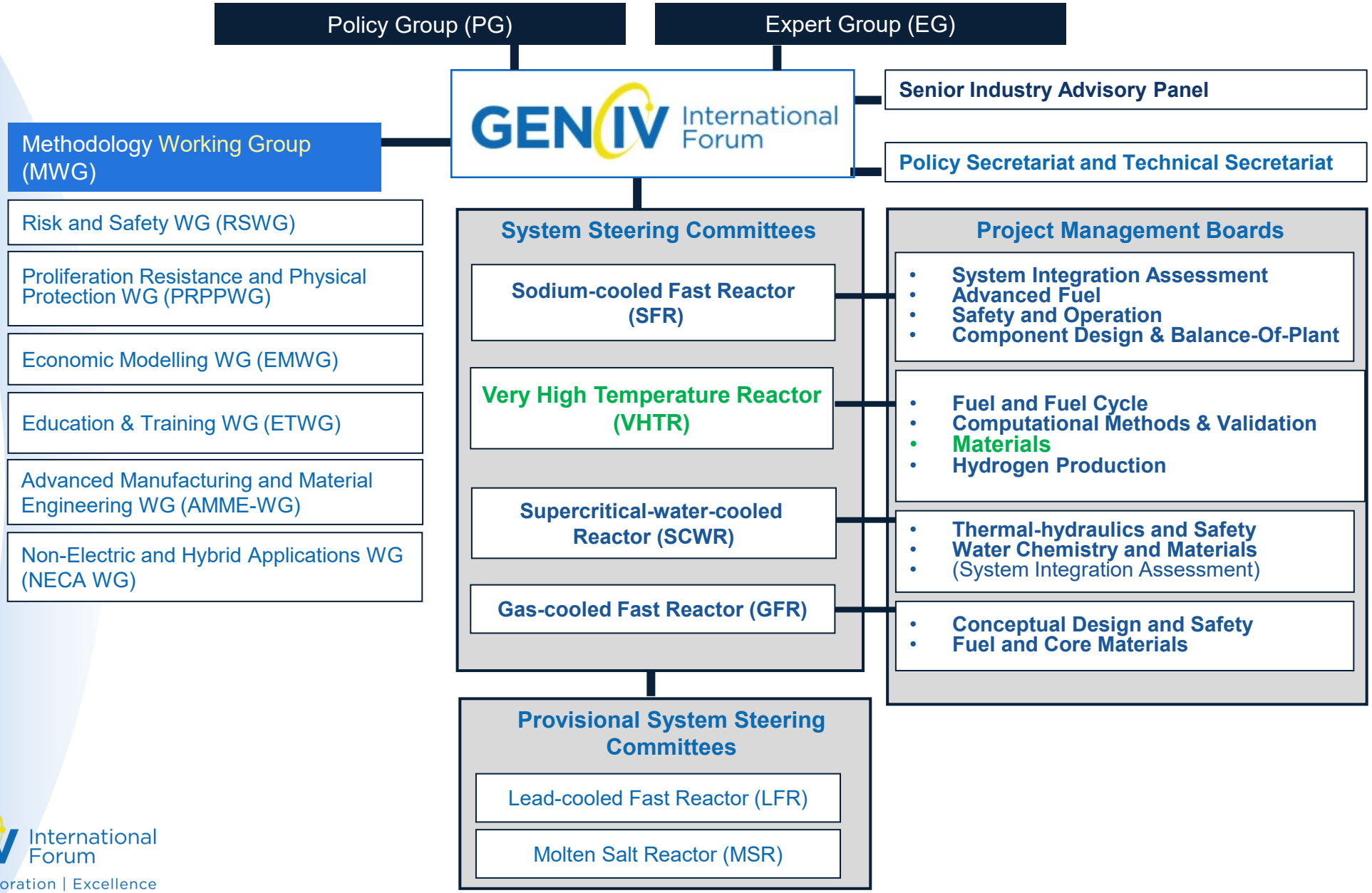


Gas-cooled Fast Reactor

LFR



Lead-cooled Fast Reactor



GEN IV International Forum
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Project Management Boards (PMBs) Oversee R&D for Specific Technical Areas for Each GIF Reactor System

Very-High-Temperature Reactor (VHTR)	Date of VHTR Project Arrangement	Signatories
Material (**MAT**)	Approved 2009 Amended 2018 2020 2022 2025	AECL/CNL (CA) ANSTO (AU) CEA (FR) DESNZ (UK) DOE (US) INET (CN) JAEA (JP) JRC (EU) KAERI (KR) PSI (CH)
	[a]Withdrawn	NRCan (CA)[a] PBMR (SA)[a]

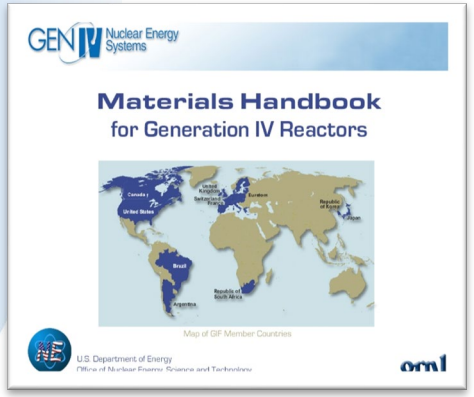
PMBs manage shared R&D: plans, schedules, funding, and deliverables—based on Signatory internal R&D programs

PMBs Oversee and Coordinate R&D within Project Arrangements

- VHTR MAT PMB addresses VHTR R&D for precompetitive issues needed for codes & standards development, enabling design, and regulatory resolution—also covers GFR materials issues
- VHTR Mat PA included legal requirements for data sharing of three separate work packages (WPs) that describe proposed R&D on
  - Graphite
  - Metals and Design Methods
  - Ceramics and Composites
- Each WP includes
  - Overall description of R&D and high-level deliverables that each participating Signatory will contribute
  - Summary of each Signatory's technical plans
  - Annual projected cost and manpower for each task by each Signatory

R&D Results from PA Are Shared among All Signatories Using Materials Handbook

- Gen IV Materials Handbook is digital database system used to collect and manage well over $300M GIF VHTR materials data
  - Includes graphite, metals, and ceramics & composites data
  - Includes technical reports, test data, materials pedigrees, microstructures, data analysis & comparison tools, etc.
  - Authoritative single source of Gen IV VHTR materials data
  - Web-based, controlled access storage and analysis, available 24/7/365
  - <u>Mandatory Handbook usage required by VHTR Materials PA</u>

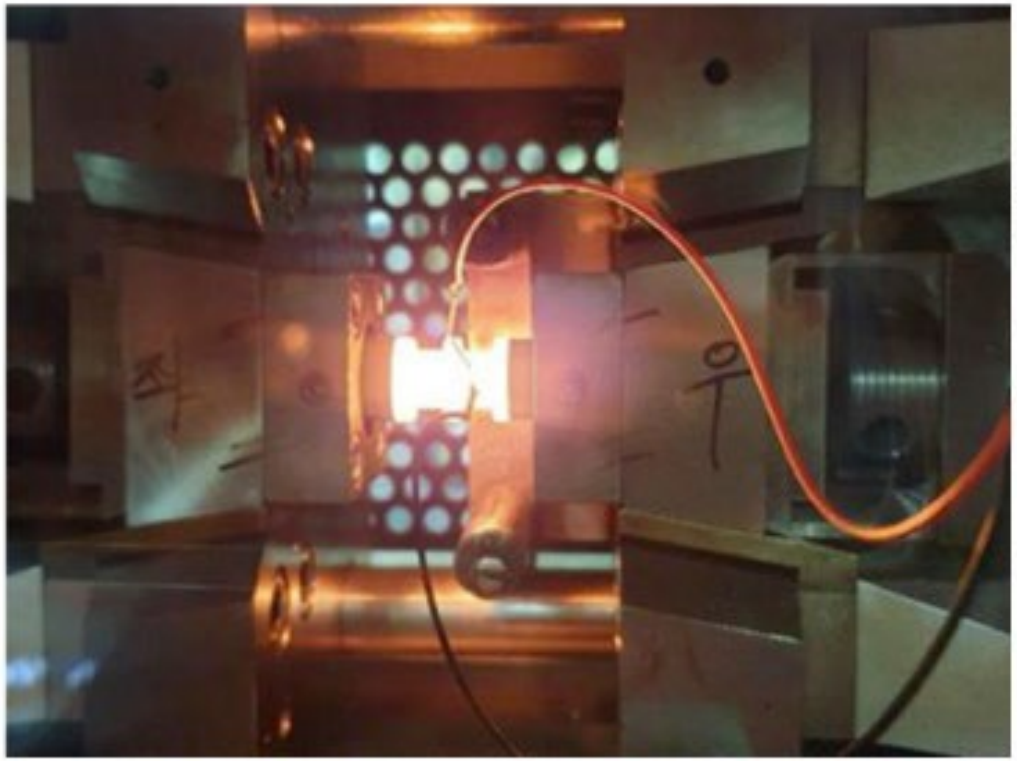


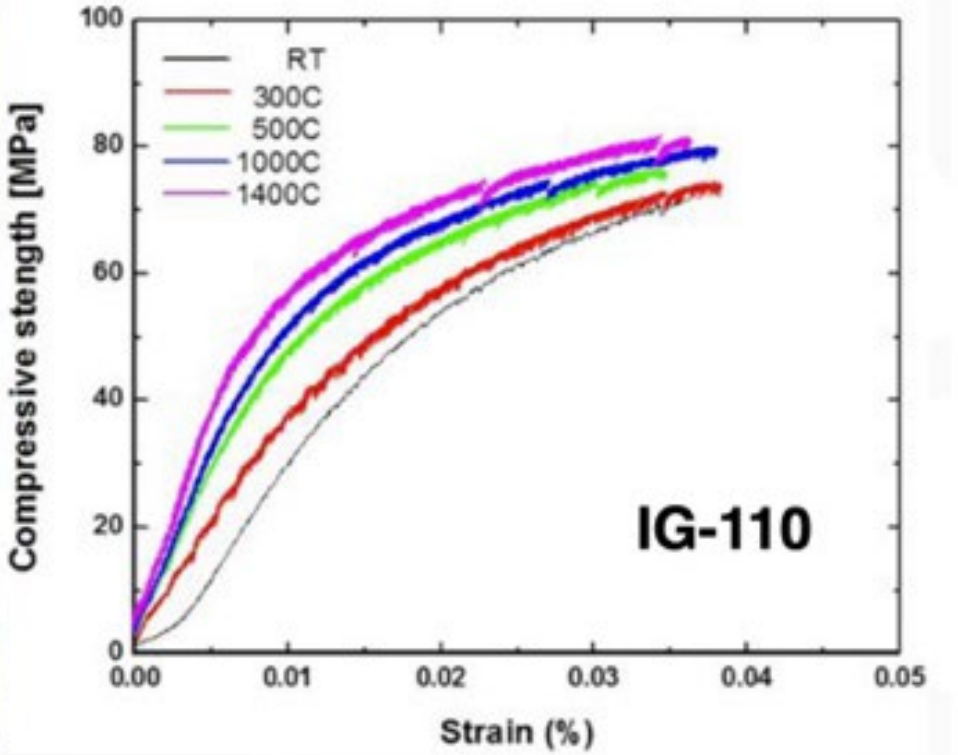
Gen IV Materials Handbook was developed and managed at ORNL by Weiju Ren from 2007-2023. Handbook operations transferred to INL in 2024 and are now managed by Courtney Otani

VHTR Materials PMB Is Cumulatively Producing Required Deliverables

- All deliverables are made available to all Signatories
- Deliverables are compiled within the Materials Handbook
  - High-level deliverables (HLDs) are jointly completed by multiple Signatories in relevant materials working groups
    - 21 HLDs have been uploaded into the Materials Handbook
  - Extensive supporting low-level deliverables (LLDs) by individual Signatories provide very valuable technical information
    - 481 LLDs have been uploaded into the Materials Handbook
  - Supporting detailed experimental data are also being shared
    - Well over 10,000 PMB materials data records & 30,000 external records have been uploaded into Handbook
  - Handbook data and deliverables are available to Signatories and to outside organizations with approval of contributing Signatory(ies)

Example of R&D Reported by KAERI under VHTR Materials PMB Graphite Working Group



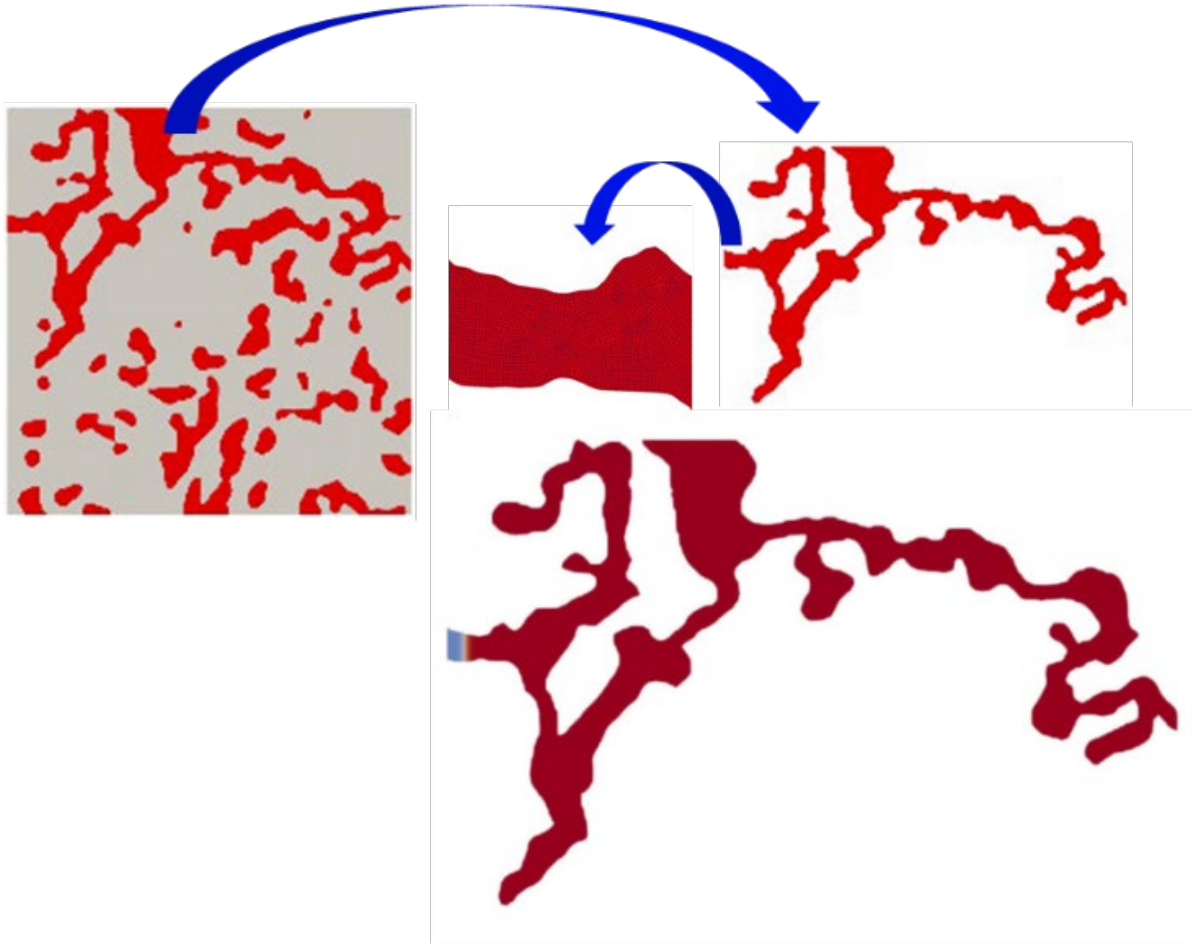


Very high temperature compression testing of graphite

Courtesy of Korean Atomic Energy Research Institute

KAERI 한국원자력연구원 Korea Atomic Energy Research Institute

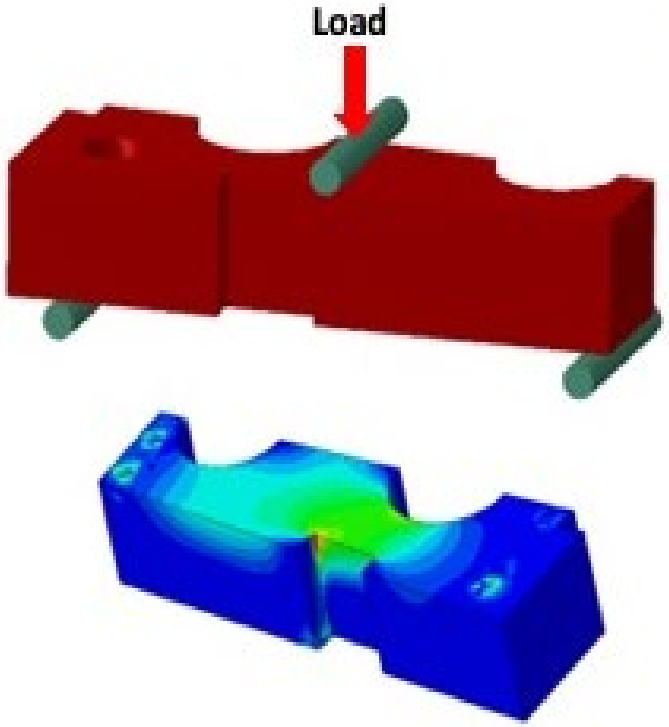
Example of R&D Reported by US under VHTR Materials PMB Graphite Working Group



Molten salt ingress into a CT slice of IG-110 graphite. Extracted 2D Geometry and Mesh (QUAD9). Molten salt in blue penetrating into the Argon filled pores in red.

Courtesy of Idaho National Laboratory

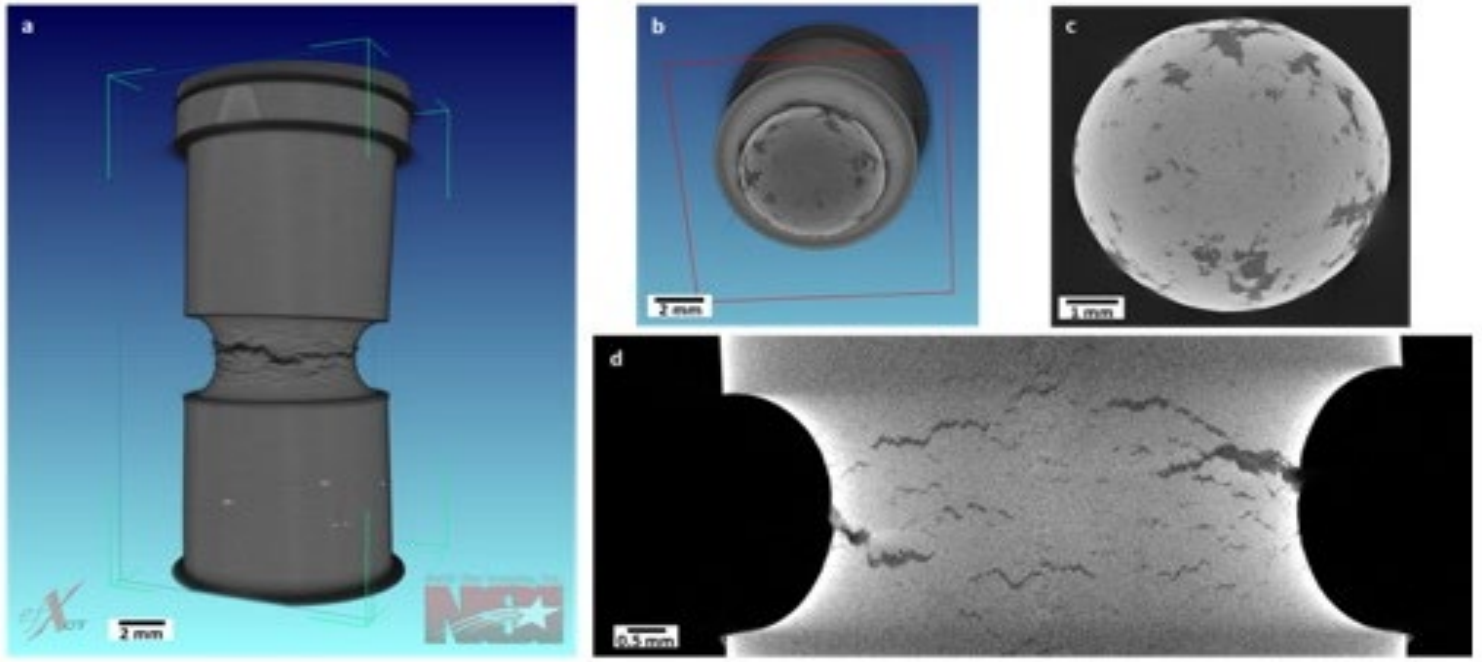
Example of R&D Reported by China under VHTR Materials PMB Graphite Working Group

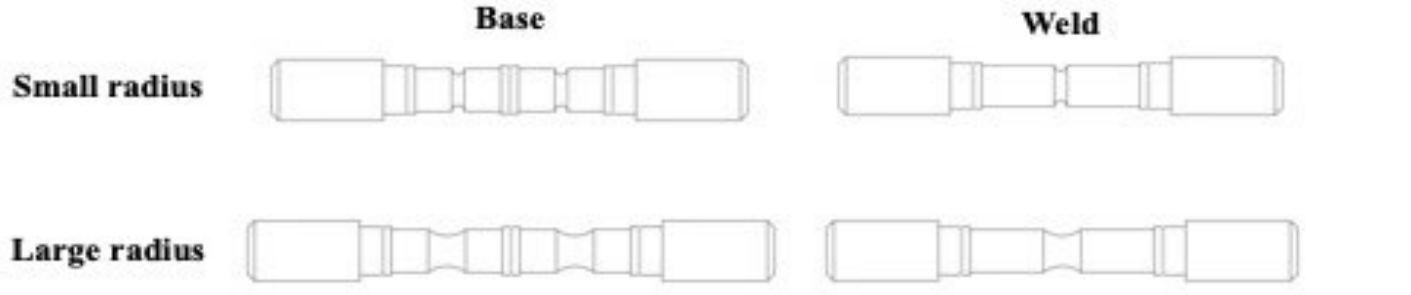


Fracture testing of large graphite blocks with complex geometry to verify failure probability calculations for HTR-PM construction.

Courtesy of Institute of Nuclear and New Energy Technology

Example of R&D Reported by US under VHTR Materials PMB Metals Working Group



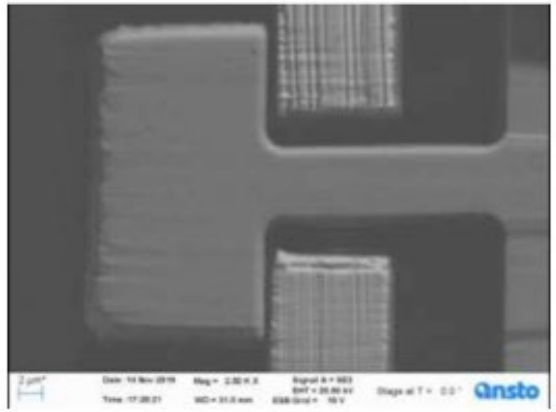


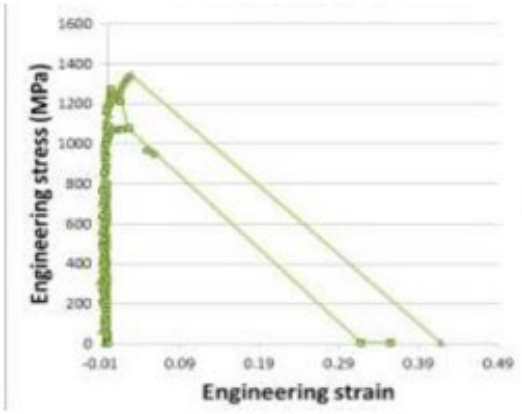
Specimen examinations for creep testing of Alloy 617 at 800°C to assess effects of notch strengthening versus notch weakening

Courtesy of Idaho National Laboratory

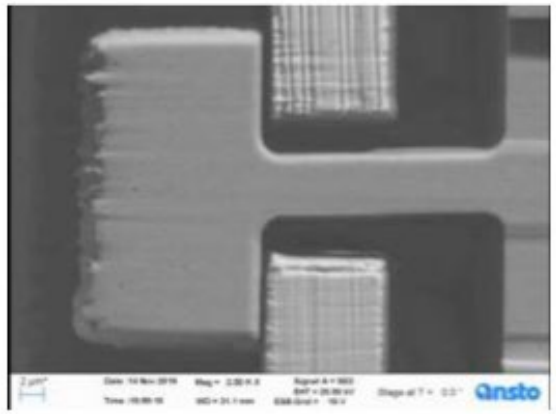
Example of R&D Reported by Australia under VHTR Materials PMB Metals Working Group

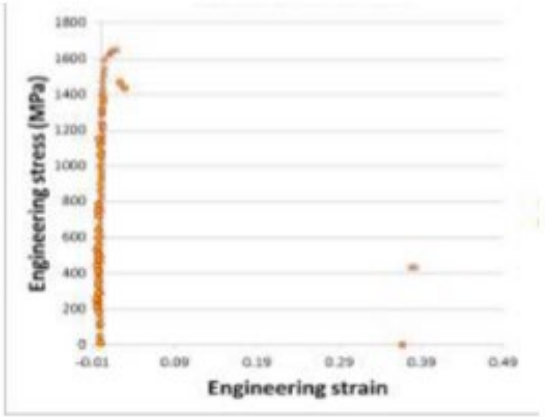
Unirradiated MA957 (S2)





Irradiated MA957 (S3)

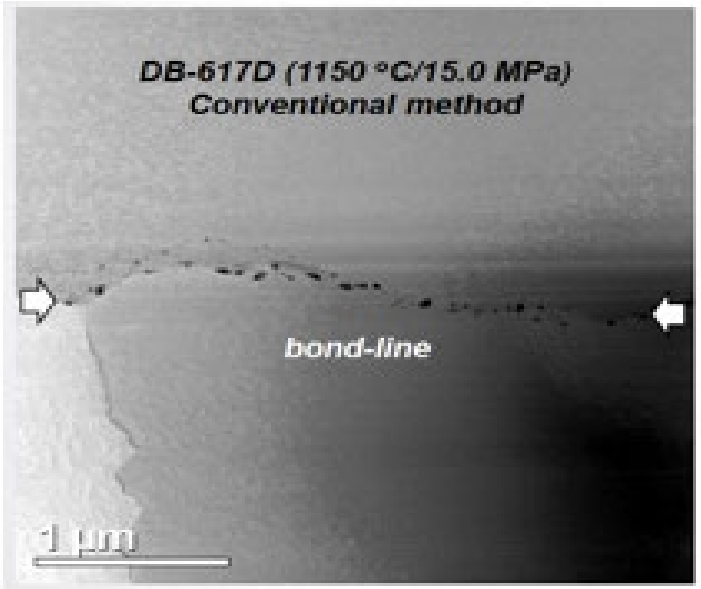


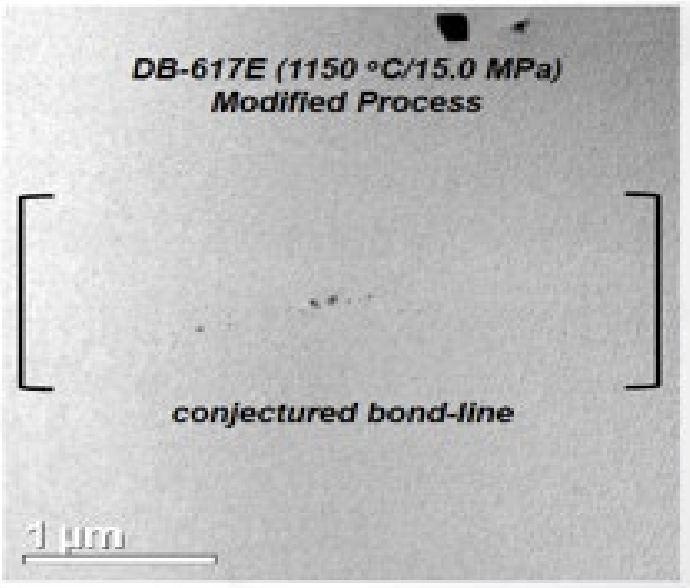


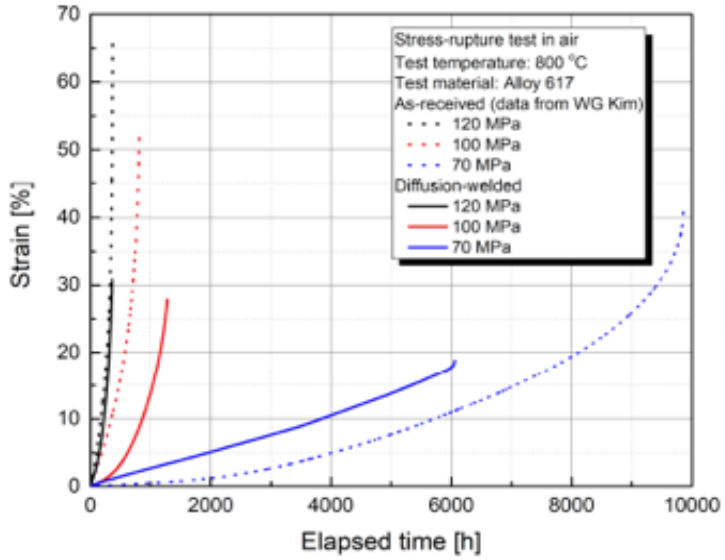
Use of in-situ nano-scale tensile specimens to evaluate irradiation effects in ion-beam exposed samples of ODS alloy MA957

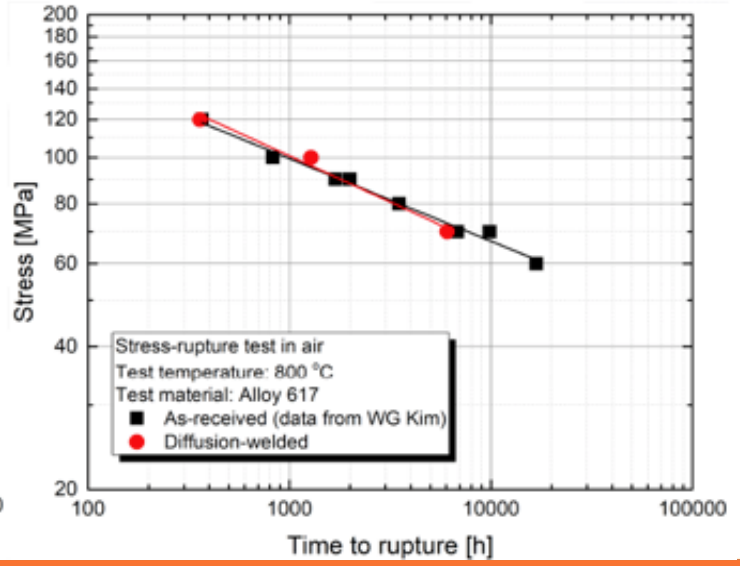
Courtesy of Australian Nuclear Science and Technology Organization

Example of R&D Reported by KAERI under VHTR Materials PMB Metals Working Group









Improvements in diffusion bonding of 617 for PCHEs to restrict the formation of Ti-rich carbides and/or Al-rich oxides at layer interfaces.

Source: The Korea Atomic Energy Research Institute (KAERI)

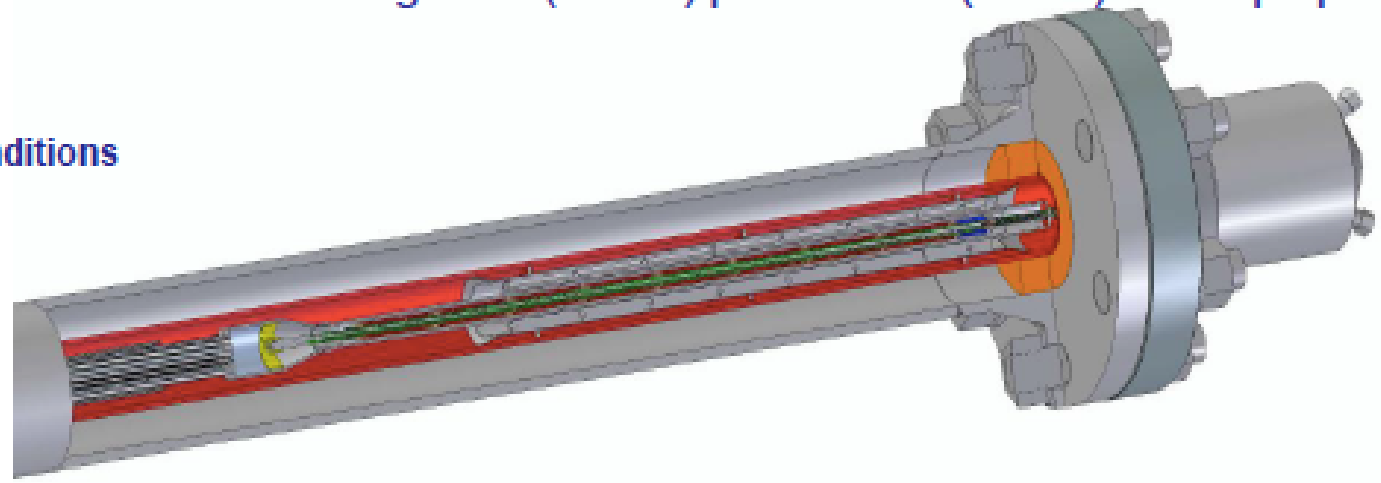
Example of R&D Reported by EU under VHTR Materials PMB Ceramics Working Group

Task 3.3 Study of SiC based clads compatibility with impure He

- Sub-task 3.3.4: Erosion and erosion/corrosion studies in high flux (90m/s) pressurized (8MPa) He loop up to 1000°C (CVR)

HTHL3 – simulating GFR fuel cladding conditions

- Temperature: 900C
- Pressure up to 8MPa
- Gas velocity: 90m/s
- Sample holder: tubular samples



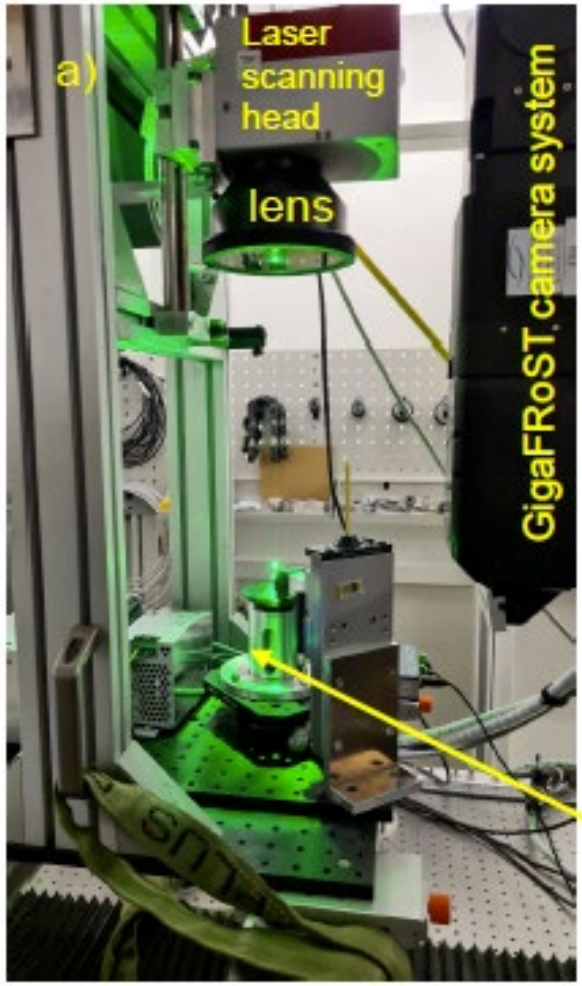
Background*:

- Only very limited information with any relevance to erosion of SiCf/SiC in a GFR environment
- Impingement angle has little effect on erosion rate
- Superior corrosion/erosion resistance of SiCf/SiC compared to metallic material 713C
- Ceramic-based cladding would perform better with regards to erosion than a metallic cladding
- Ceramic composites containing SiC would outperform other bulk ceramics
- Most oxidation studies on SiCf/SiCm composites have been carried out at atmospheric pressure
- No studies have been conducted at GFR representative pressures and flow

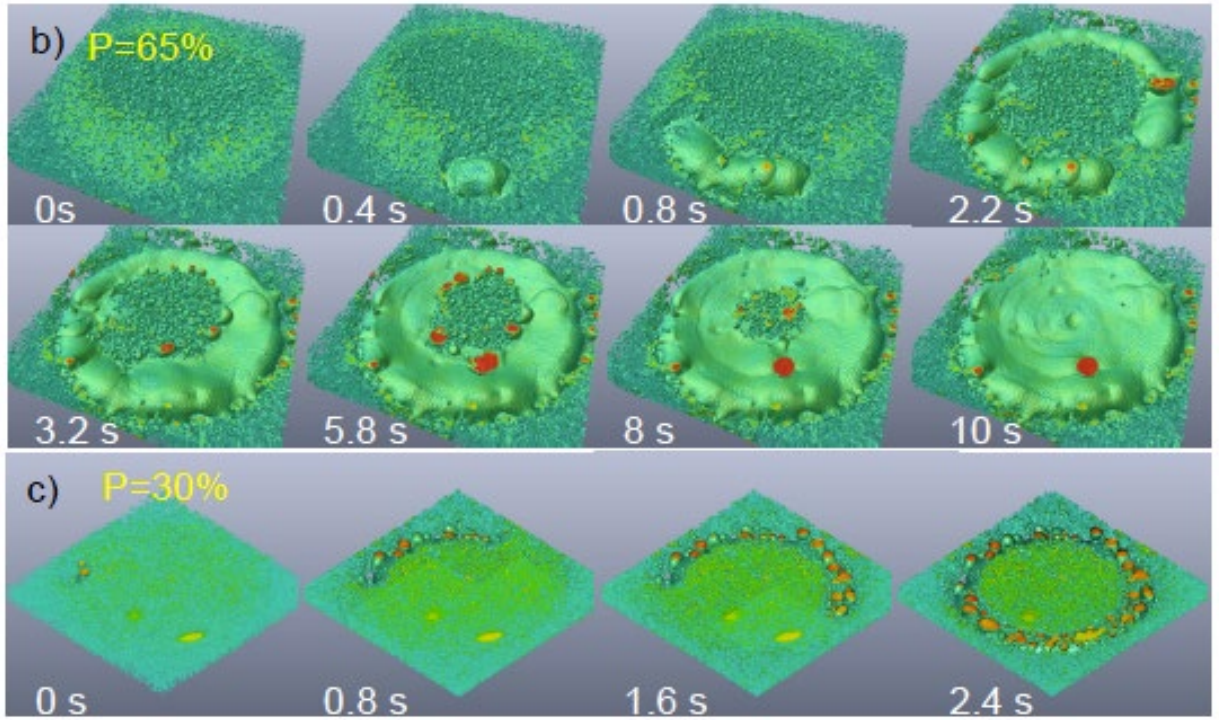
**Conclusions of NNL D3.31 Matisse Report*

Courtesy of EU MATISSE Project

Example of R&D Reported by PSI under VHTR Materials PMB Ceramics Working Group



3,000 rpm



Operando tomography during PBF-LB of alumina-effect of different laser power.

Courtesy of Paul Scherrer Institute (PSI)

Collectively, VHTR Materials PMB Is Providing Technical Bases for Improved Codes & Standards

- First new high-temperature construction material in 20 years added to ASME Code
  - Alloy 617, high-temperature nickel-based alloy for steam generator & heat exchanger applications, approved for ASME Section III Division 5 for High Temperature Reactor Construction Materials
  - Technical bases largely provided by joint CEA, DOE, and KAERI data
  - Allows usage for 100,000 hrs at temperatures to 950°C
- Graphite and Ceramic Composites rules added to Section III Division 5, plus supporting ASTM testing standards
  - Based largely on technical input largely provided by joint DOE, EU, JAEA, KAERI, and PBMR
  - Includes novel rules for non-ductile materials design and usage, including environmental and irradiation effects

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GAS-COOLED REACTOR

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By participating in GIF, DOE-NE is heavily leveraging their own R&D funding for developing and qualifying advanced reactor materials

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