High Temperature Moderator Overview

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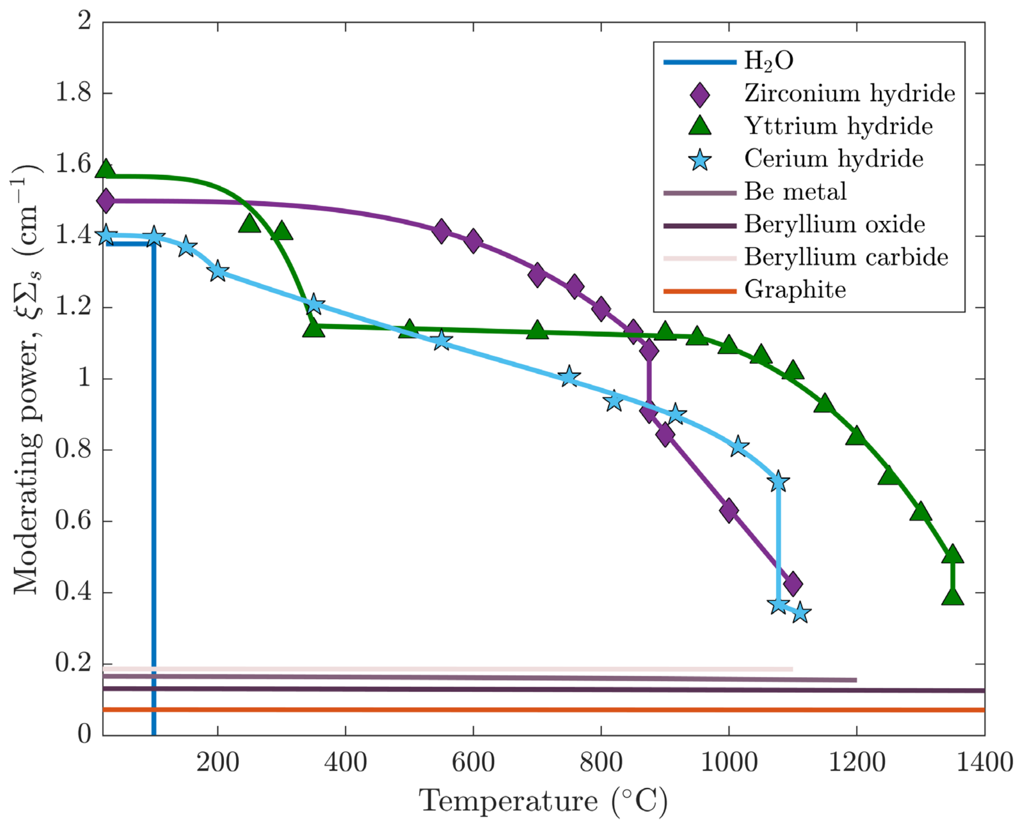
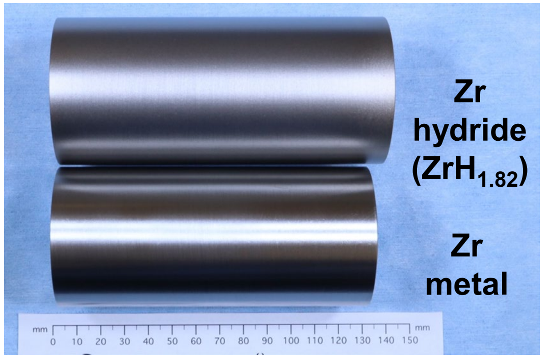
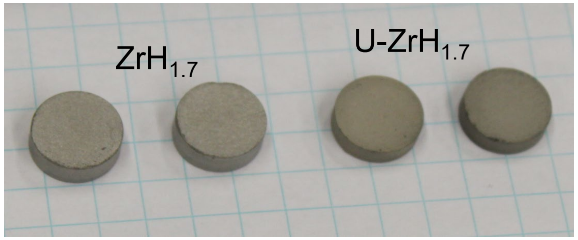
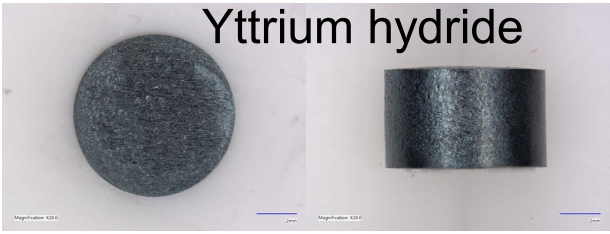
Why use a metal hydride moderator?









- High moderating power due to hydrogen density
- YH and ZrH have a good balance of low neutron absorption and good high temperature stability

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Main operational Differences between YH and ZrH

- High temperature behavior (without cladding)
  - YH is better
- Behavior under high hydrogen partial pressure (without cladding)
  - YH could gain hydrogen and become YH_3, which is very likely to pulverize/crumble
- Cladding plenum pressure
  - ZrH has a higher plenum pressure, higher burst risk
  - Possibly higher permeation through cladding with higher plenum pressure. No known thermal testing data of ZrH in cladding.
- Material availability
  - Y readily available is higher in oxygen content, which lowers the hydrogen density
  - Nuclear grade Zr is difficult to obtain. Zircalloy-4 is one option. High purity Zr cracks easily and experiences significant grain growth in hydride form.
- Neutronic penalty
  - Zr is better

Hydride releases H until it reaches equilibrium partial pressure inside the cladding

δ-ZrH1.6 → 1 atm @ 800C
ε-ZrH1.85 → 30 atm @ 800C
δ-YH1.9 → 0.5-1 atm @ 800C

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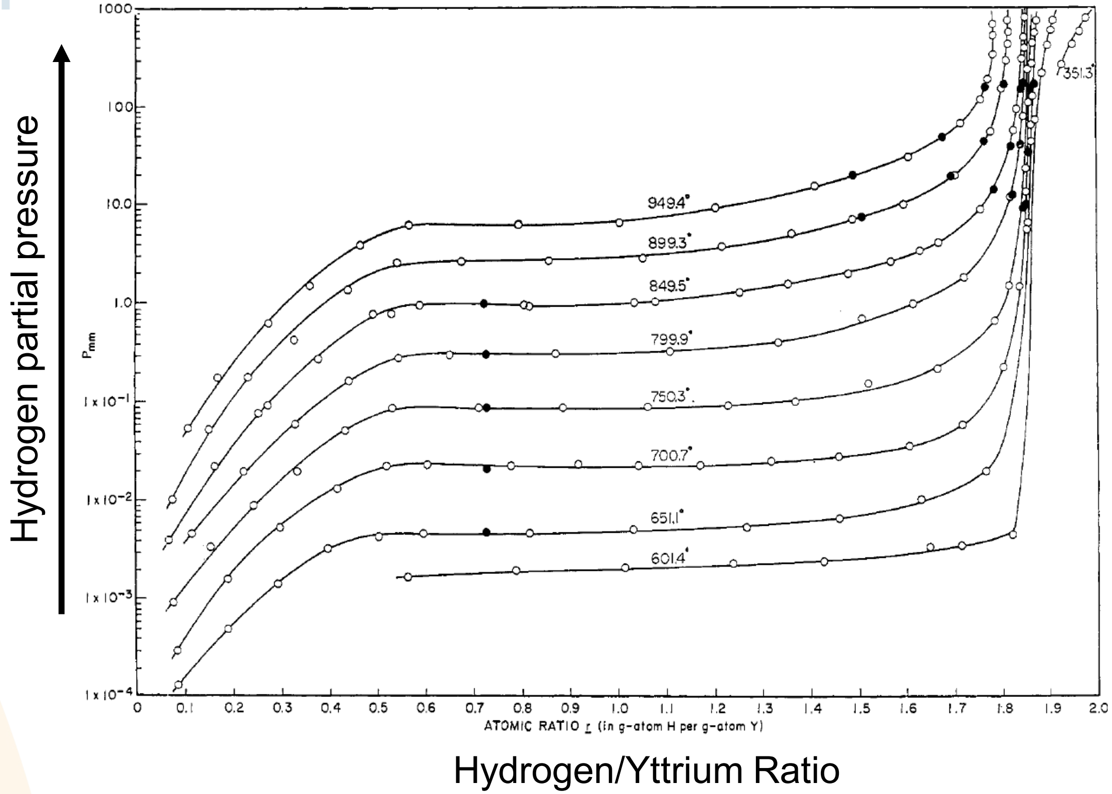
Phase stability depends on temperature and H_2 pressure



Yannopoulos, Edwards, and Wahlbeck (1984) Journal of Physical Chemistry

- You need a higher H_2 partial pressure to stabilize the same H/M at higher temperature
- This partial pressure can build up naturally from H release at high temperature in a good cladding

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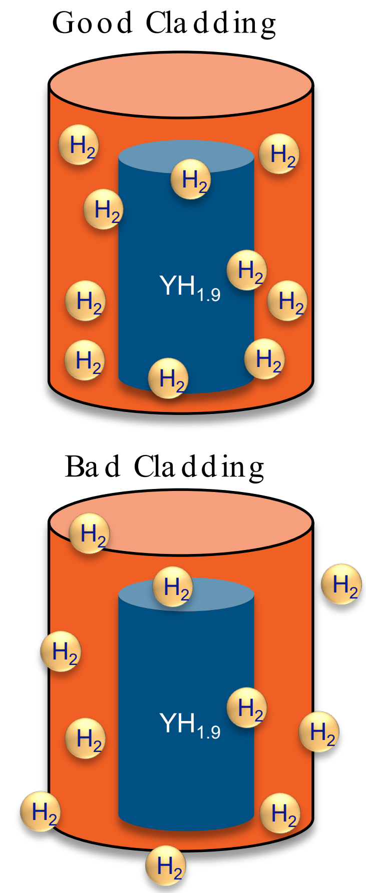
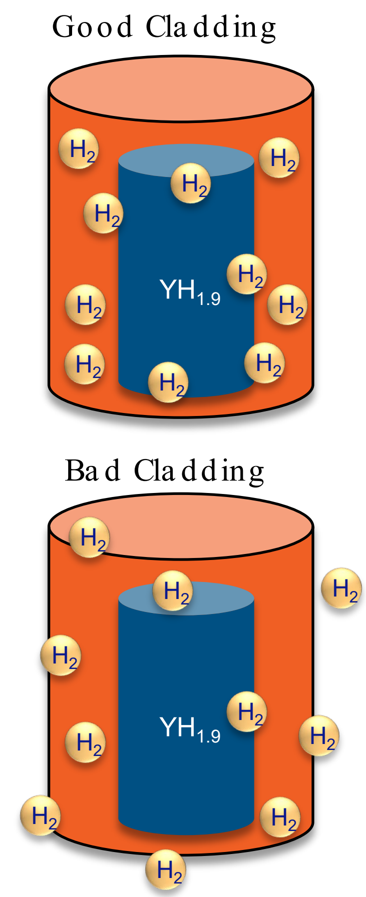
Cladding is needed for high temperature operation



Hydrogen release from YH in vacuum at 700ºC

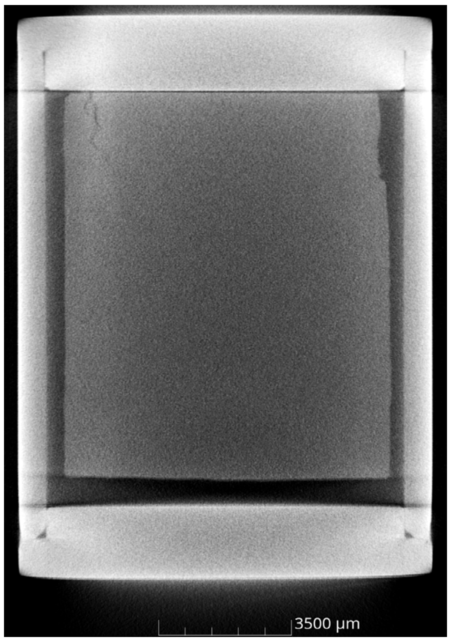
Cladding is needed for high temperature operation

$YH_{1.9}$ releases hydrogen until a partial pressure of ~0.1 atm is reached at 800C

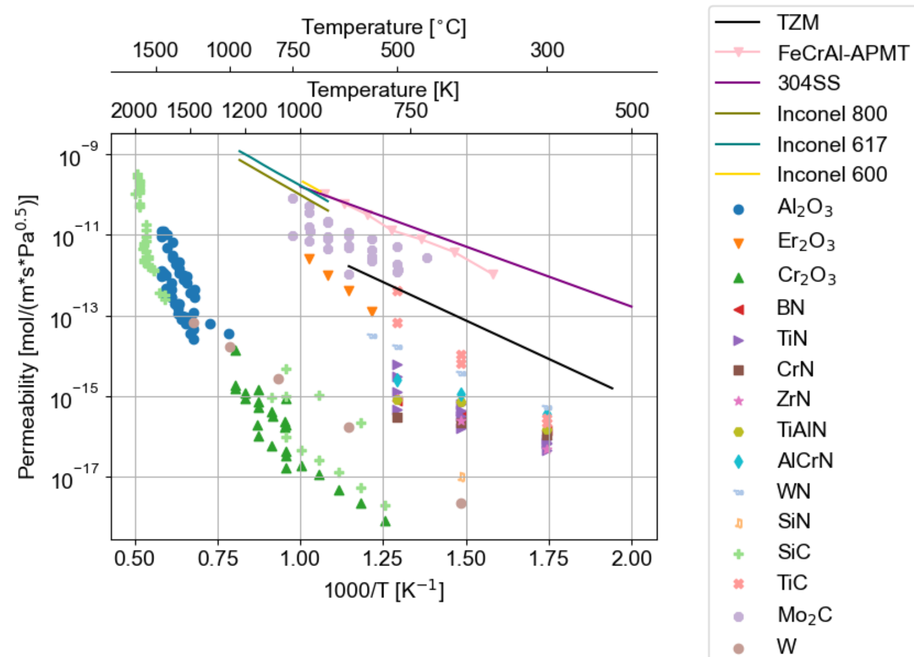


Pressure Composition Temperature Curve

Cladding selection is based on several properties

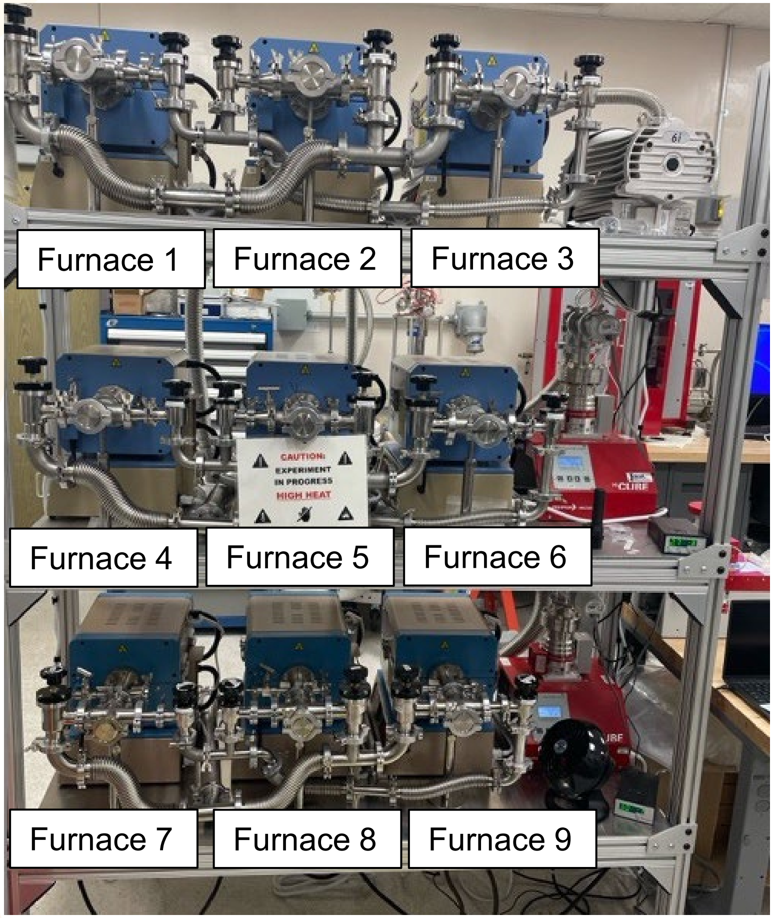


XCT image of yttrium hydride in TZM



1) Hydrogen permeation
2) Neutronics
3) Material availability, machinability
4) Thermal stability (e.g. CTE mismatch)

Quantifying moderator element performance



- Prototype moderator elements are weighed every 100h of thermal testing to quantify hydrogen loss
- Compared with hydrogen permeation models

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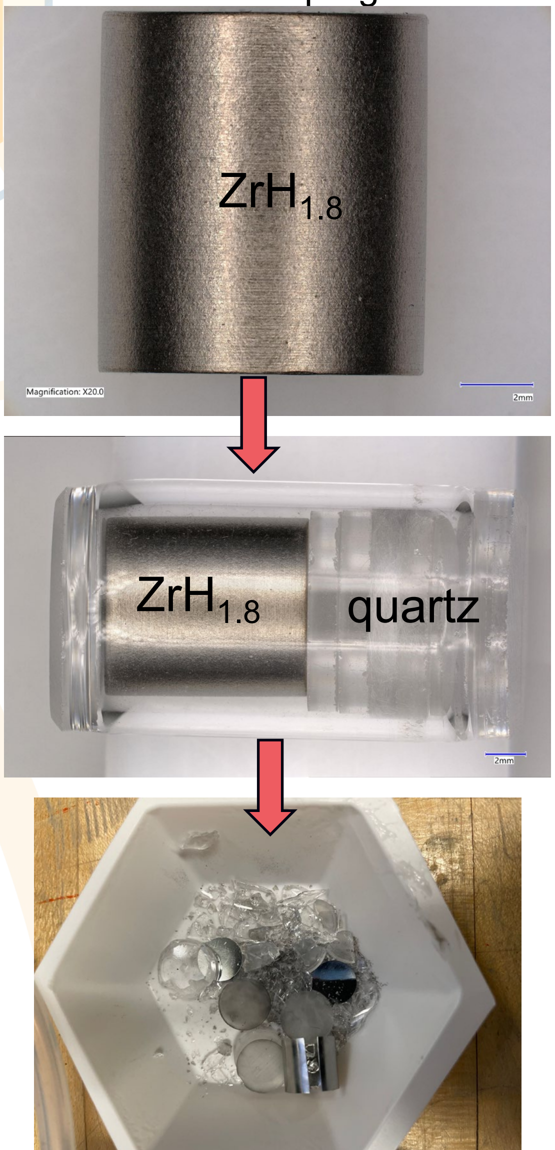
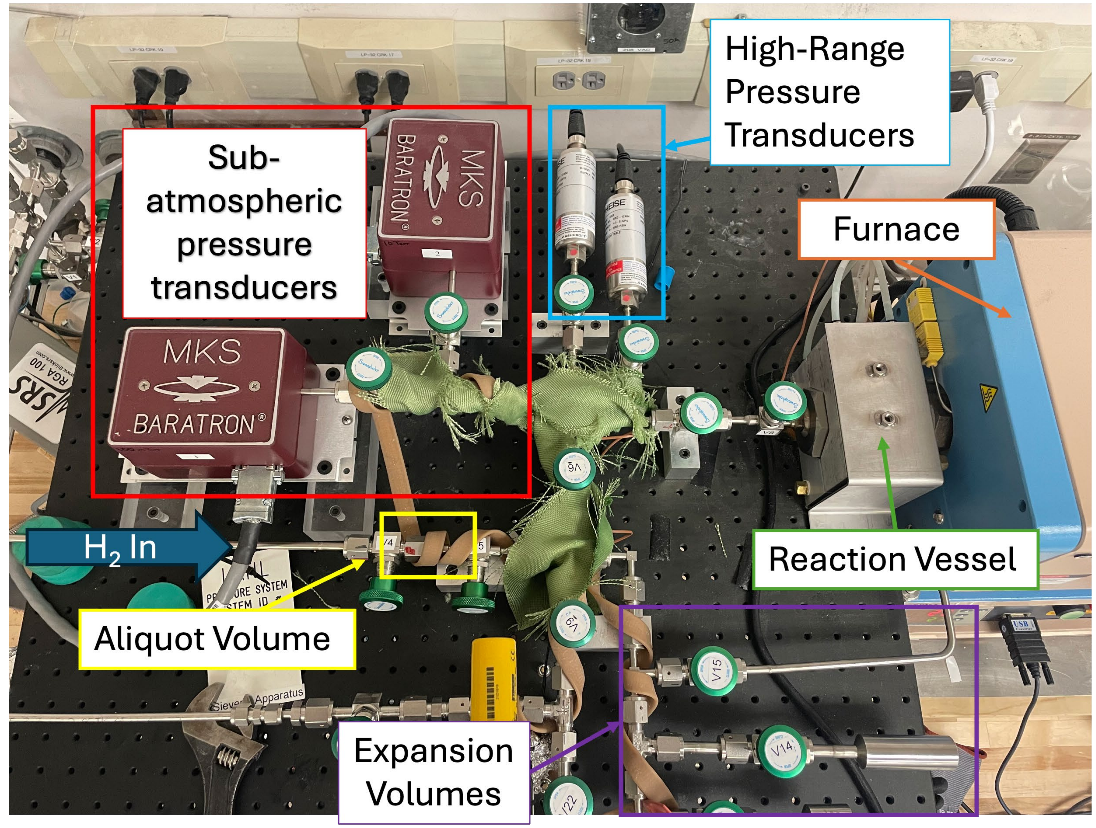
Moderator cladding burst testing

Samples prepared under NASA FSP program





- $ZrH_{1.8}$ is heated to 800°C in a Sievert's apparatus
- Sample reaches high internal partial pressure (>10 atm), causing the quartz to burst
- Pressure is measured at burst and used to back-calculate the pressure inside the quartz

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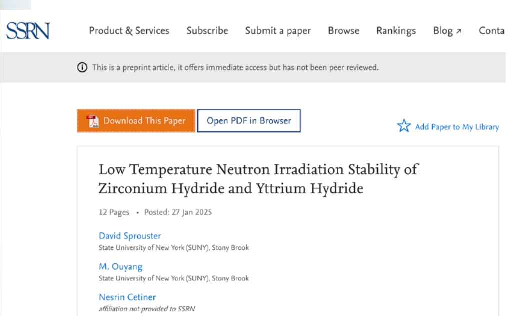
Advanced Moderator Handbook overview

- The goal of the Handbook is to provide scientists and reactor designers with a set of physical and thermal property data for metal hydride moderators.
    - Previously focused on yttrium hydride
    - Last FY we incorporated zirconium hydride
- Topics included are summarized in the flow chart to the right
- Last FY we incorporated newly available irradiation data for YH and ZrH
- This FY we incorporate hydrogen containment methods



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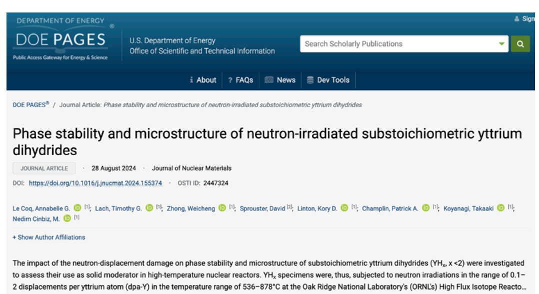

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Phase stability and microstructure of neutron-irradiated substoichiometric yttrium dihydrides

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Le Coq, Annabelle G. [1]; Lach, Timothy G. [1]; Zhong, Weicheng [1]; Sprouster, David [2]; Linton, Kory D. [1]; Champlin, Patrick A. [1]; Koyanagi, Takaaki [1]; Nedim Cinbiz, M. [1]

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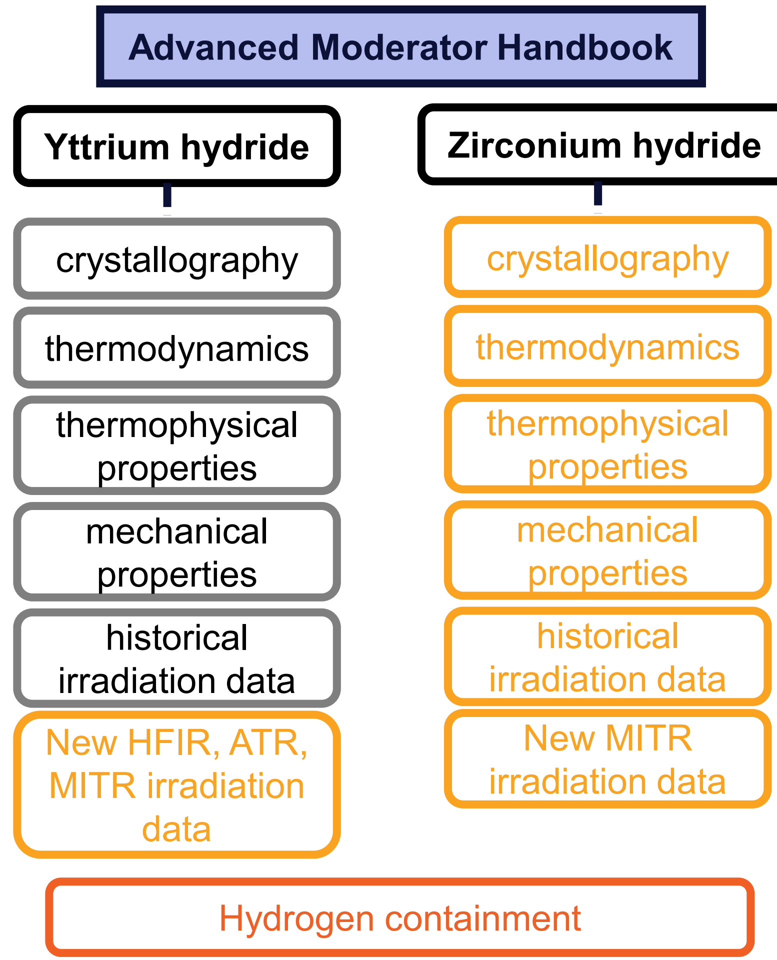
The impact of the neutron-displacement damage on phase stability and microstructure of substoichiometric yttrium dihydrides (YH_x, x <2) were investigated to assess their use as solid moderator in high-temperature nuclear reactors. YH_x specimens were, thus, subjected to neutron irradiations in the range of 0.1–2 displacements per yttrium atom (dpa-Y) in the temperature range of 536–878°C at the Oak Ridge National Laboratory's (ORNL's) High Flux Isotope Reacto...



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