INL/MIS-24-78895-Revision-0

TRISO Fuel for High-Temperature Passively-Safe Nuclear Reactors

June 2024

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Changing the World's Energy Future

Idaho National Laboratory

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TRISO Fuel for High-Temperature Passively-Safe Nuclear Reactors

Multiple barriers to fission product release

Kernel:
- Retains actinides and lanthanides as oxides or carbides.
- Retains 40-90 % of fission gases.

Buffer:
- Stops fission recoils before reaching denser layers.
- Acts as plenum to retain fission gases not retained in kernel.

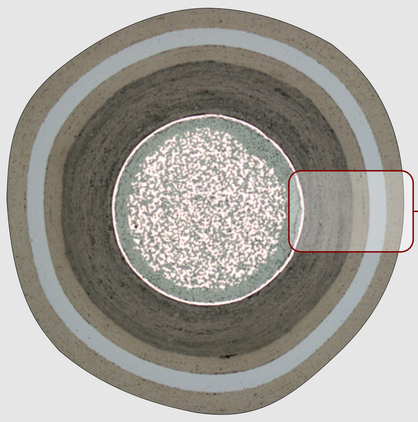
[1]IPyC:
- Protects the kernel from chlorine compounds during deposition of the SiC layer via *CVD.
- Hermetic, retains fission gases in case of failure of SiC or OPyC layers.

[2]SiC:
- Primary structural layer responsible for strength and retention of metallic fission products.
- Protects kernel from contaminants in helium coolant.

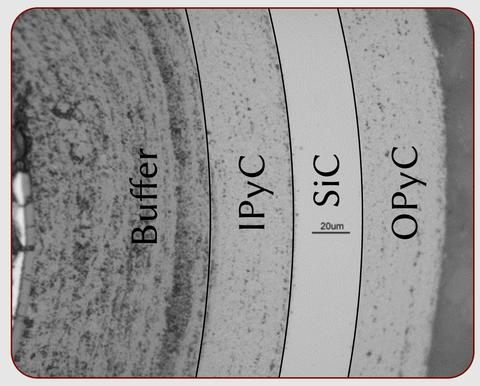
[3]OPyC:
- Protects particles during overcoating to fabricate compacts or pebbles.
- Hermetic, retains fission gases in case of failure of SiC of IPyC layers.

Graphite matrix:
- Retains thousands of TRISO particles in protective fuel element (compact or pebble).
- Retains metallic fission products that escaped from defective particles or via diffusion through intact TRISO coatings due to long times at high temperatures.

TRISO Cross-section



Zoomed-in layers



[1]Inner Pyrocarbon
[2]Sillicon Carbide
[3]Outer Pyrocarbon
*Chemical Vapor Deposition

Thermal stability

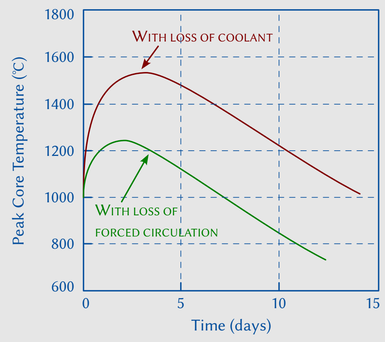


Fig: Temperature vs. Time for loss of forced convenction

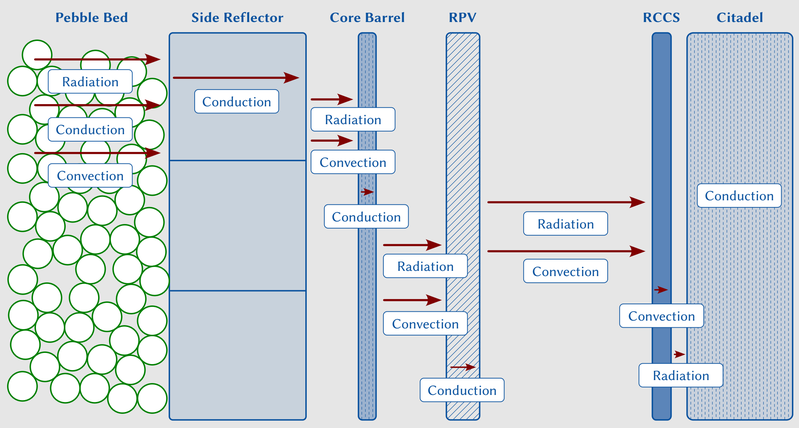
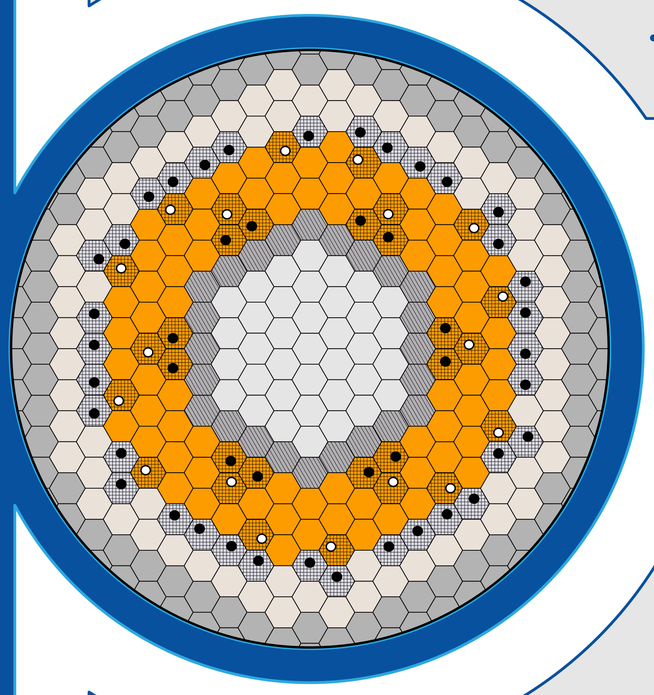
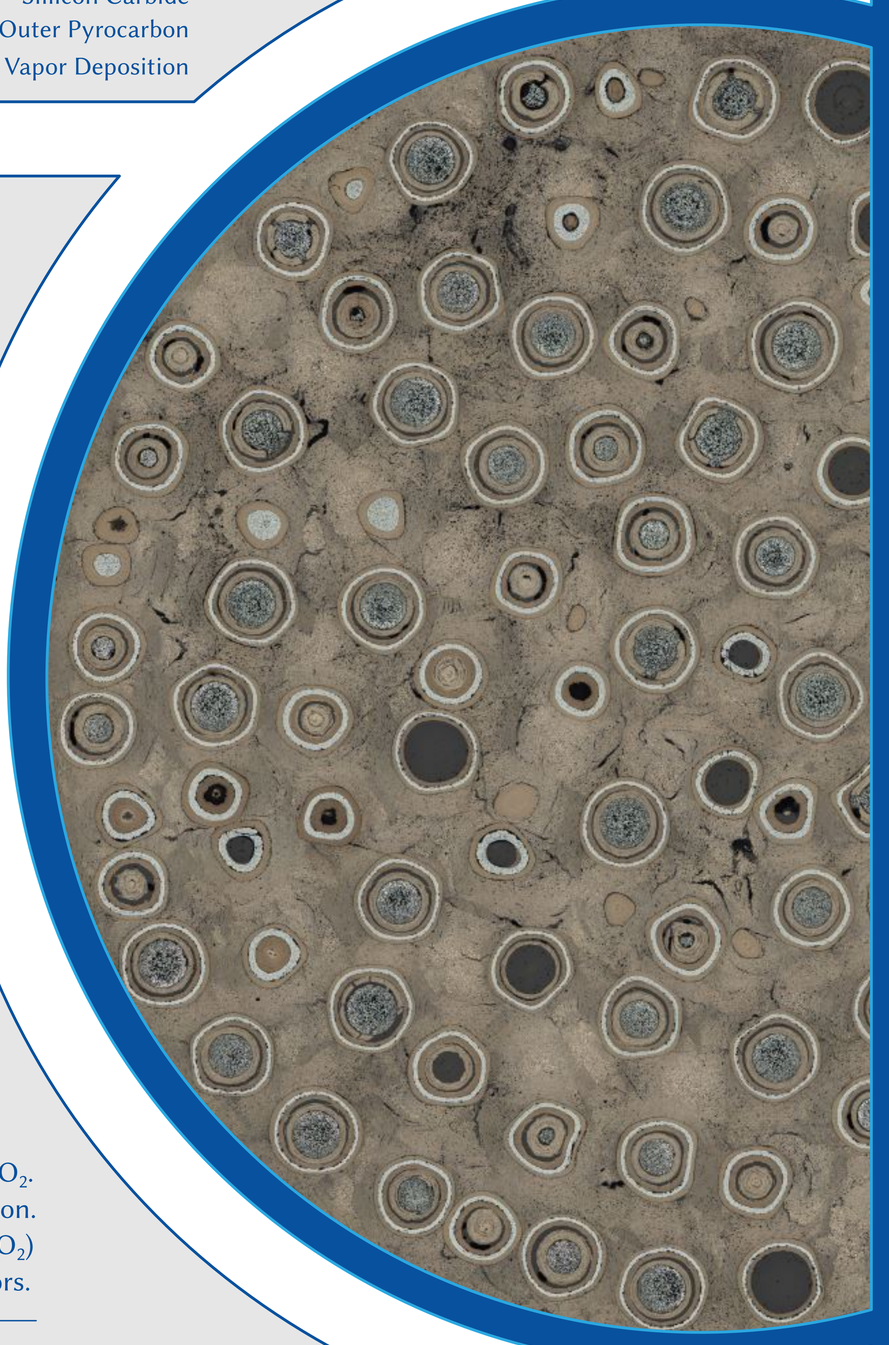


Fig: Temperature vs. Passive heat transfer mechanisms

- Heterogenous mixture of UO_2 and UC_2 kernel melts at 2790 ℃.
- SiC layer starts to decompose at temperature ~2000 ℃, PyC stable at 2000 ℃+.

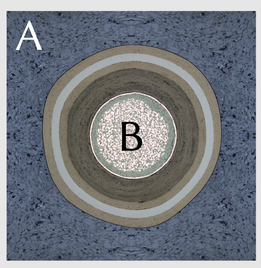




Chemical compatibility

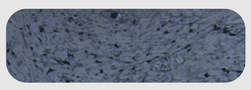
- IPyC layer reduces SiC- fission product interactions.

***UCO Fuel Kernel:**
- Reduces $CO_{(g)}$ formation compared to only UO_2. No CO attack of SiC. Reduced kernel migration.
- Suited to higher burnup (~20% vs. ~11% for UO_2) and temperature gradient in prismatic reactors.



Graphitic matrix:
- Gives some protection to particles from contaminant or accidental introduction of oxidants into reactor.

A: Graphite matrix



B: UCO Kernel

*Uranium Oxycarbide

Safety & Performance

- TRISO fuel acts as "functional containment" for fission products. Safety-significant containment building not needed.
- Large mass of graphite in core slows temperature changes.
- Design limits off-normal peak fuel temperature to < 1600 ℃.
- Meltdown not possible.
- Fuel and reactor together constitute a thermally and chemically stable system.

Fig: Coupling to the Industrial Process

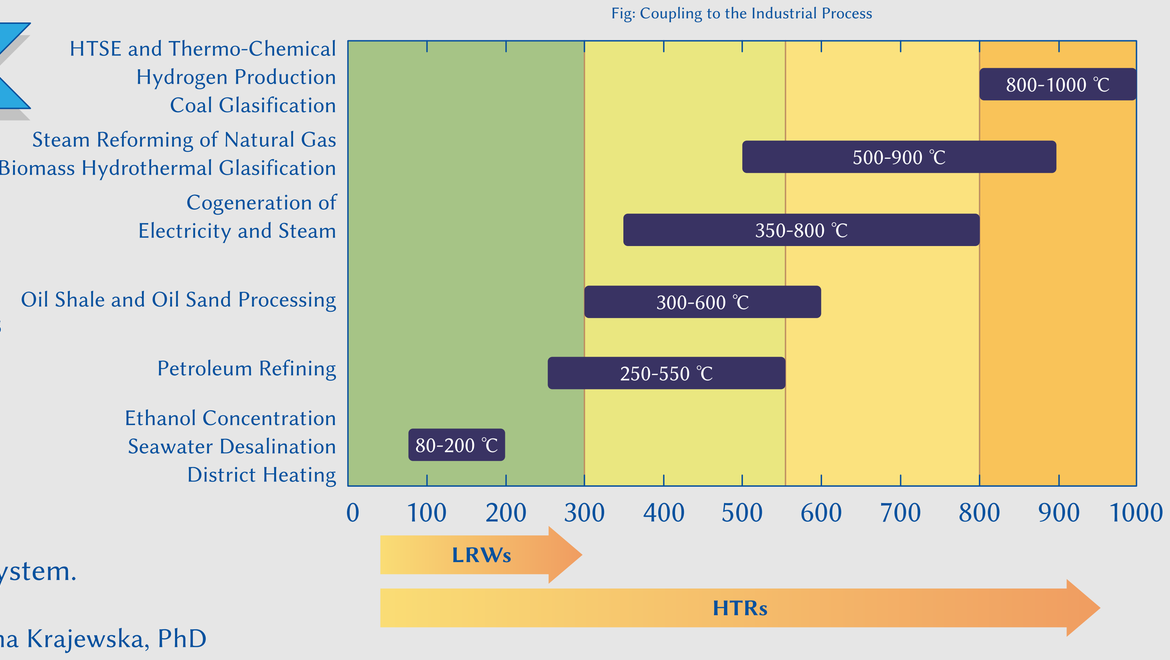
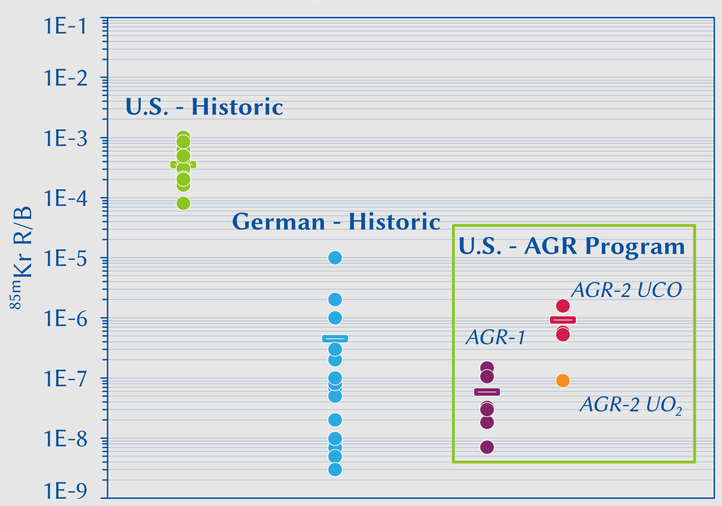


Fig: Fuel Irradiation performance



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