U.S. DEPARTMENT OF ENERGY | Office of Nuclear Energy

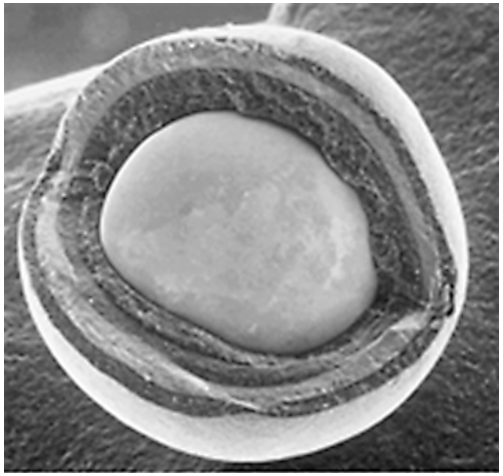
Nuclear Energy University Program FY19 CINR FOA

Program Supporting: Nuclear Reactor Technologies

HTGR TRISO Fuel Particle Materials (RC-4)

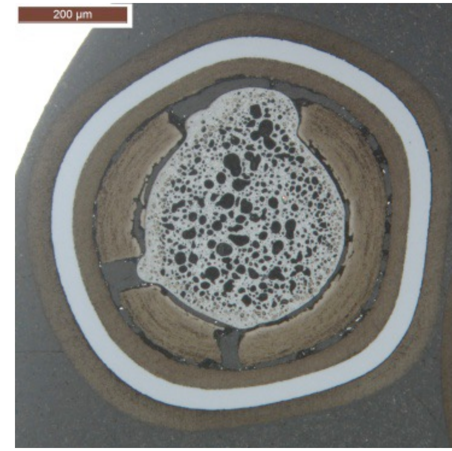
TRISO FUEL BUFFER LAYER BEHAVIOR DURING IRRADIATION (RC-4.1)

ROBUST INDIVIDUAL TRISO-FUELED PEBBLE IDENTIFICATION METHOD FOR EX-CORE EVALUATION (RC-4.2)



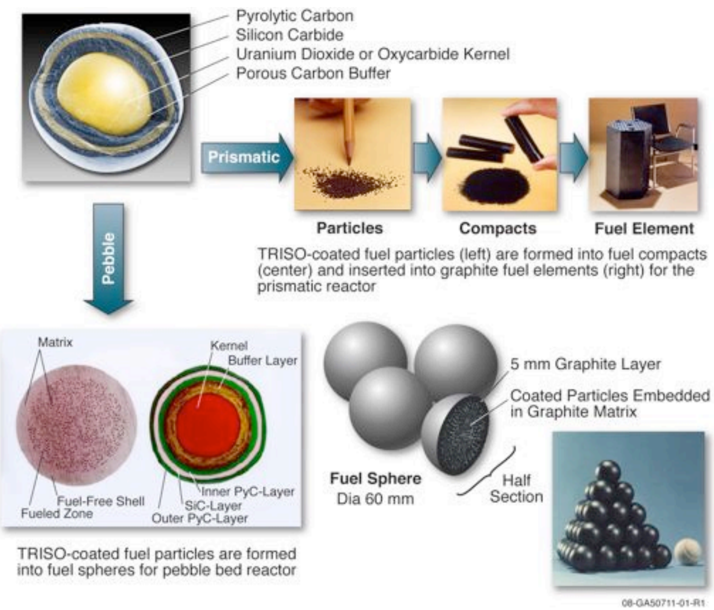
Gerhard Strydom
ART Gas-Cooled Reactor
National Technical Director

TRISO FUEL BUFFER LAYER BEHAVIOR DURING IRRADIATION (RC-4.1)



Motivation for research:

- **More insight** is needed to correctly model TRISO fuel performance in simulation codes, e.g., PARFUME.
- Inner PyC (IPyC) coating mechanical failure exposes the inner SiC surface to fission product attack, primarily Pd.
- Buffer properties and bond strength with IPyC layer data (irradiated, un-irradiated) may not be known for use in models for performance simulation codes.
- Need to explicitly **model buffer/IPyC layer evolution as a function of neutron irradiation**, i.e., how the buffer interacts with IPyC layer during irradiation as buffer densifies and shrinks.

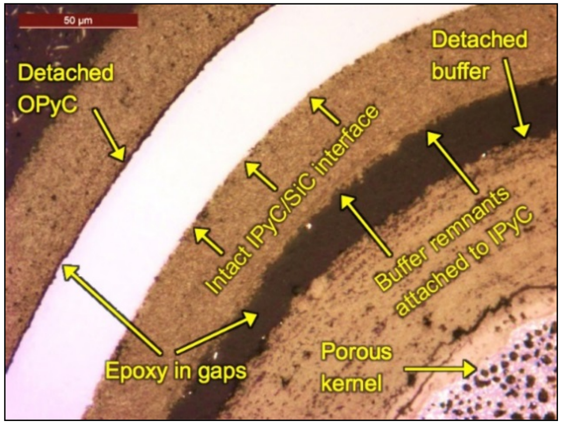


Eligible to Lead: Universities Only
Maximum funding: $800,000
Duration: Up to 3 years

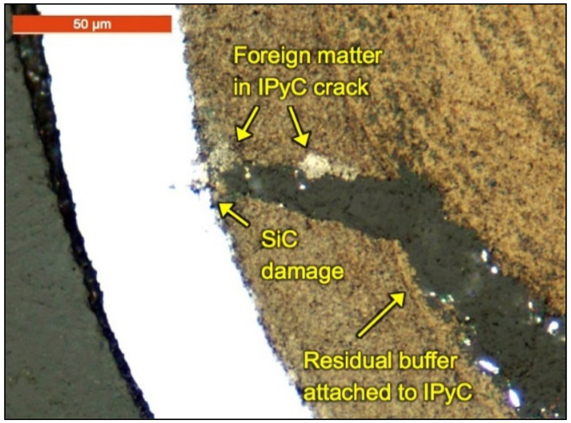
HTGR TRISO Fuel Particle Materials (RC-4)

Proposals for RC-4.1 should:

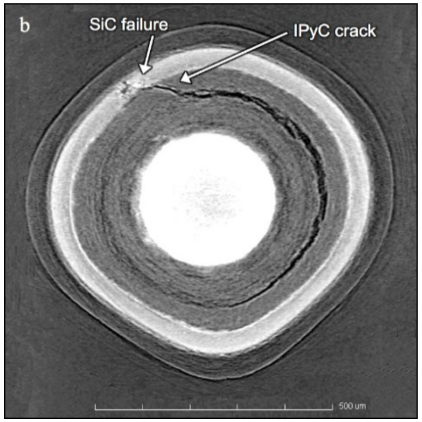
- **Focus on modelling TRISO particle buffer/IPyC evolution and failure mechanisms.**
- **Consider what parameters have the greatest impact on TRISO particle fuel buffer/IPyC evolution and failure mechanisms.****



Example of preferred buffer evolution: buffer shrinkage does not affect outer layers



Example of IPyC crack and SiC degradation from partial buffer detachment



Example of IPyC crack and SiC degradation from partial buffer detachment

RC-4.1 proposals should develop new models that capture the kernel, buffer, and IPyC phenomena observed in AGR irradiation tests and PIEs.

** Blaise Collin, William Skerjanc, "Assessment of Material Properties for TRISO Fuel Particles used in PARFUME," Idaho National Laboratory, INL/EXT-18-44631, Rev. 0, 2018.

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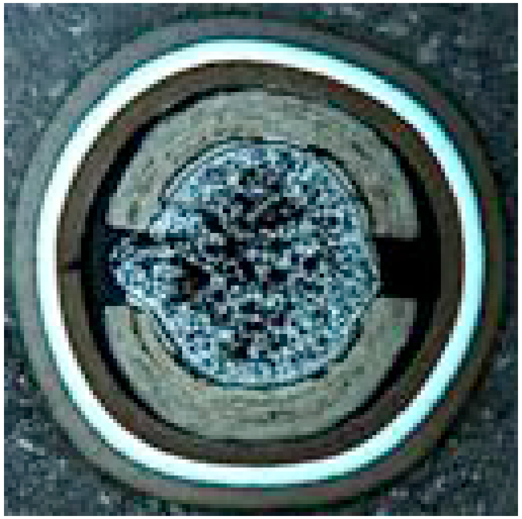
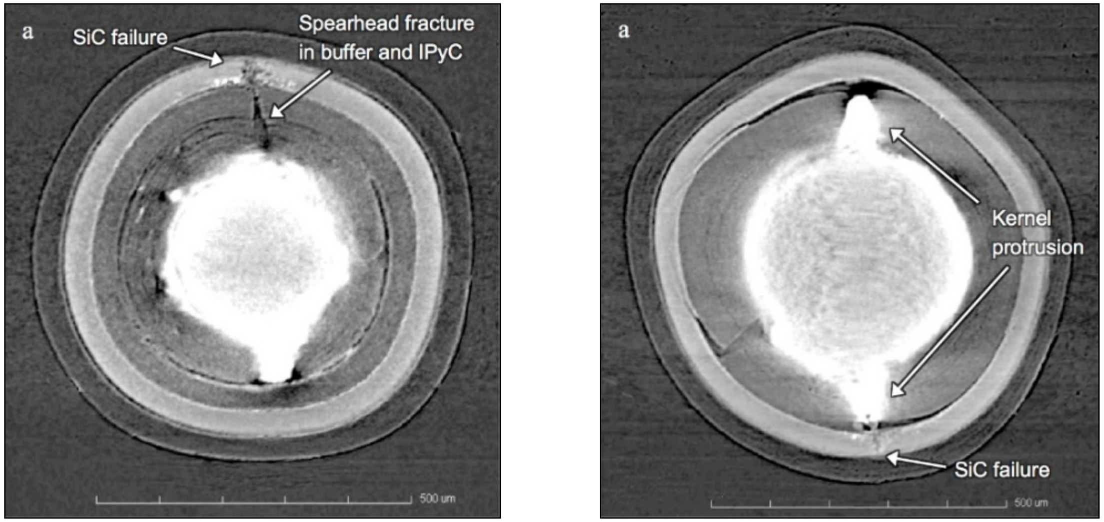
Proposals for RC-4.1 should:

- Capture the **effects of neutron irradiation** on TRISO IPyC layer, buffer and kernel and **use parametric studies over a range of material properties** where existing properties do not currently exist.

- Use **realistic** ranges for HTGR temperatures, TRISO fuel temperatures, neutron damage rates, based on **vendor** design information.



Irradiated TRISO



Examples of IPyC cracks causing SiC degradation and fracture because buffer was not detached where buffer fractured

HTGR TRISO Fuel Particle Materials (RC-4)

The primary thrust is on new models; however, proposals for RC-4.1 may:

- **Consider performing separate effects experiments where results could be used to develop behavioral or material property correlations that may be applied in TRISO fuel performance models.**
- **Use university research reactor tests with surrogates or experiment with non-irradiated TRISO fuel specimens.**
- **Develop new property measurement techniques that could be used potentially in glove boxes or hot cells for obtaining data from radioactive specimens.**
- **Produce new microscopy results using actual AGR TRISO program irradiated specimens to develop specific data that describes buffer/IPyC interaction phenomena for correlations and model development.**
- **Use actual Advanced Gas Reactor (AGR) TRISO Fuel irradiated test specimens at NSUF locations for hot-cell PIE, SEM, TEM, FIB microscopy, etc.**

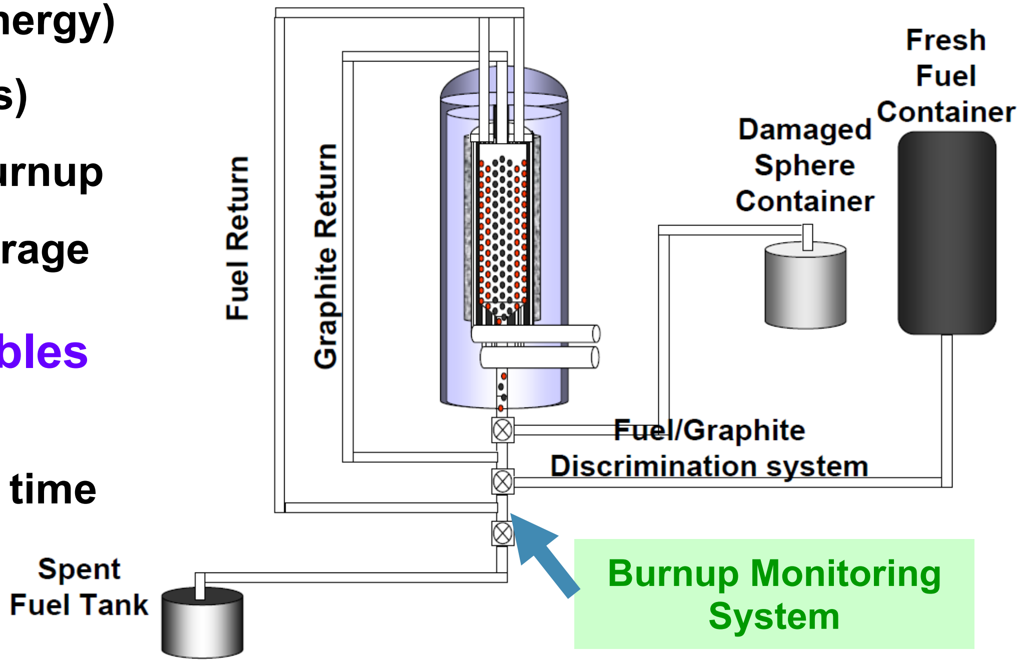
Suggestions:

- **Coordinate and partner with AGR TRISO Fuel Program lab staff to get access to appropriate specimens, advice about implementing new measurement methods in hot cells.**
- **Contact TRISO fuel and reactor vendors about their fuel and system normal operational and accident scenario conditions.**

ROBUST INDIVIDUAL TRISO-FUELED PEBBLE IDENTIFICATION METHOD FOR EX-CORE EVALUATION (RC-4.2)

Motivation for this research:

- Pebble bed fuel moves stochastically through core
  - Gas-cooled: downward (e.g., X-energy)
  - Salt-cooled: upwards (e.g., Kairos)
  - Ex-core monitoring system for burnup
  - Core reinsertion or spent fuel storage



Tagging, tracking individual pebbles would be useful for:

- Determining individual residence time
- Avoiding excessive burnup
- Reducing uncertainty in pebble "flow line" computational models
- Addressing material control and accountability, and proliferation resistance issues

Eligible to Lead:	Universities Only
Maximum funding:	$800,000
Duration:	Up to 3 years

ROBUST INDIVIDUAL TRISO-FUELED PEBBLE IDENTIFICATION METHOD FOR EX-CORE EVALUATION (RC-4.2)

Proposals for RC-4.2 should:

- **FOCUS** on obtaining a **robust, reliable** tagging method that can handle:
  - Potential abrasion, corrosion, or degradation of pebble surface
  - High temperature, high neutron flux environment
  - Track and catalogue large number of pebbles (hundred of thousands)
  - Ex-core pebble burnup measurement systems (neutron, gamma)
  - Relatively rapid “reading” time ≤ burnup measurement system time to meet pebble throughput requirements.
  - Track each individual pebble’s being reinserted into the core or sent to spent fuel storage
- **MAY** develop new computational algorithms or models that use this pebble tagging and tracking method and its data for reducing the uncertainty of pebble flow simulation models.
- **NOT** develop new burnup measurement/monitoring systems

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Proposals must NOT repeat research or earlier tests performed by NEUP grants and the AGR TRISO Program**

Proposals that develop new measurement methods may repeat some previous research to qualify and benchmark these measurement techniques.

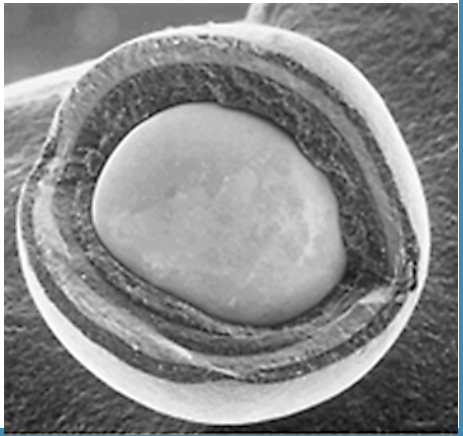
RC-4.1 proposals should use AGR TRISO program microscopy (SEM/TEM) results to benchmark any computational models or correlations developed for describing buffer/IPyC behavior.

RC-4.2 proposals should NOT develop ex-core burnup monitoring systems, but focus on pebble tagging and tracking methods.

** **See INL Advanced Reactors Technology, AGR TRISO fuels, NGNP, NEUP websites at:**

https://art.inl.gov/default.aspx

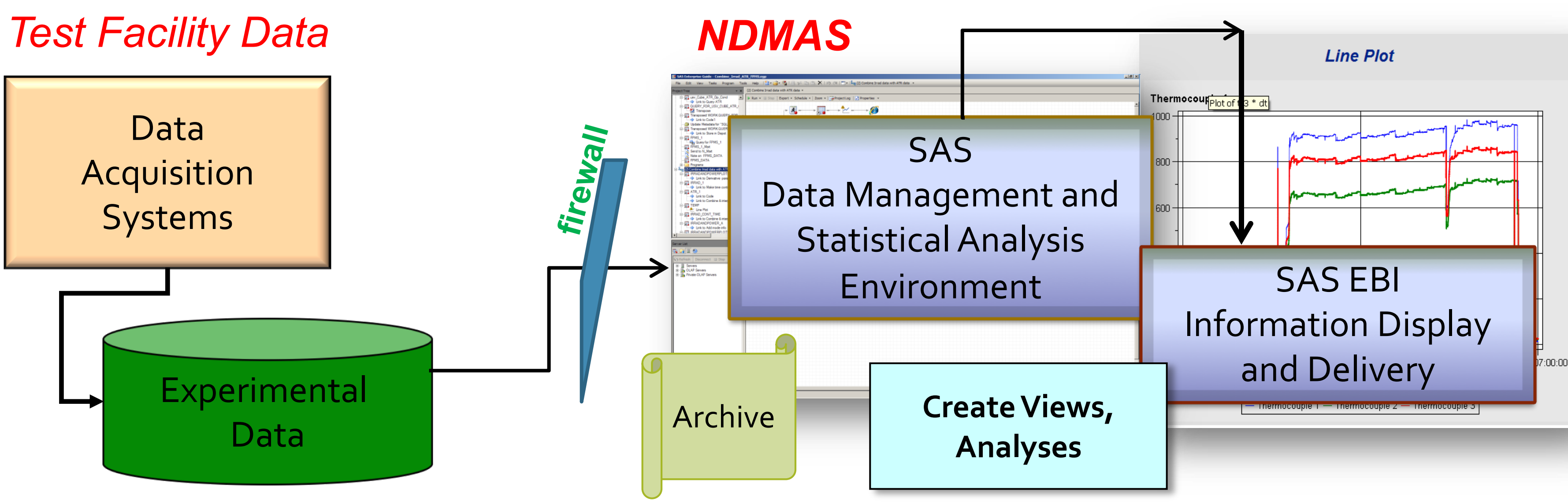
https://neup.inl.gov



Quality Assurance Compliance

Quality Assurance and Data Retention:

- Data collection, experiments, data validation, and verification may require compliance with NQA-1 2009 and 2009 NRC accepted paragraphs.
- Archiving data and simulation results in the INL Nuclear Data Management and Analysis System (NDMAS) may be required



Interested university applicants may contact:

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