GEN IV International Forum
Expertise | Collaboration | Excellence

Approach to Waste Characterization and the Use of Synroc Technology, particularly in the Applications for Advance Reactors and Future Fuel Cycles

Daniel Gregg and Anton Peristyy

18 February 2026

cea
INL Idaho National Laboratory
Pacific Northwest NATIONAL LABORATORY
CHALMERS UNIVERSITY OF TECHNOLOGY
Australian Government
ANSTO

Some Housekeeping Items

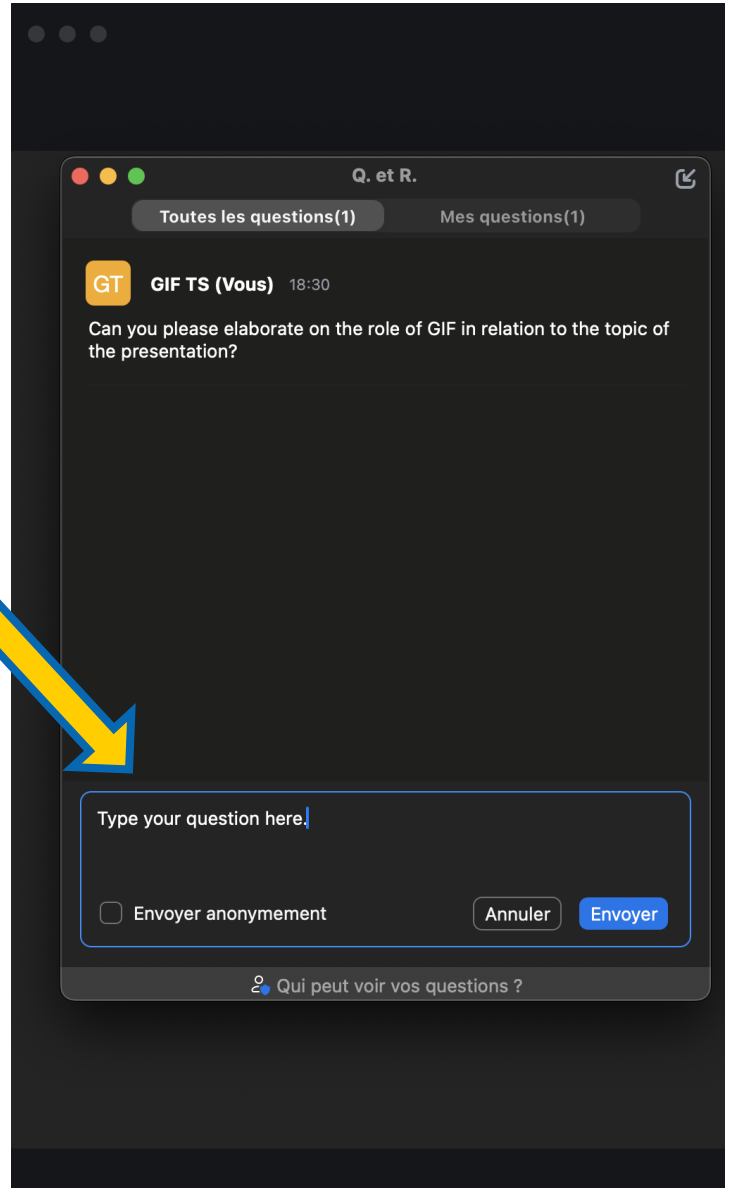
Listen through your computer	Please select the “use computer audio” option and check that your speakers/headphones are not muted.
Technical Difficulties	Search the Zoom Webinars Support https://support.zoom.com/hc/en/article?id=zm_kb&sysparm_article=KB0064143
To ask a question	Select the “Q&A” pane on your screen and type in your question
Share with others or watch it again	A video/audio recording of the webinar and the slide deck will be made available at www.gen-4.org
Please take the survey	A brief online survey will follow the webinar.

GEN IV International Forum
Expertise | Collaboration | Excellence

To Ask a Question – Use the Q&A function

Click the Q&A buton in the zoom menu.

You will then see a window that will allow you to type your question.



GEN IV International Forum
Expertise | Collaboration | Excellence

Approach to Waste Characterization and the Use of Synroc Technology, particularly in the Applications for Advance Reactors and Future Fuel Cycles

Daniel Gregg and Anton Peristyy

18 February 2026

Australian Government | ANSTO

Meet the Presenters

Dan Gregg is Manager of Wasteform Engineering at ANSTO, where he leads the development and implementation of advanced technologies for the safe immobilization of radioactive waste. With extensive experience in nuclear waste treatment and materials engineering, Dan specializes in designing tailored wasteforms for challenging radioactive waste streams. He has played a key role in advancing ANSTO's Synroc technology, including its application in a first-of-a-kind facility designed to convert radiopharmaceutical liquid waste into a disposal-ready form. Dan's work supports sustainable nuclear technologies by delivering practical, scientifically robust solutions that meet stringent regulatory requirements and enable long-term waste disposition strategies.

Anton Peristyy is Nuclear Waste Characterisation Lead at ANSTO. His focus is the characterisation of radioactive wastes to support Synroc waste treatment technologies. Anton's primary area of expertise includes development, validation, and implementation of analytical methods for chemical and radiological characterisation of nuclear wastes. Anton delivers highly accurate and precise methodologies for waste sampling and characterisation at various ANSTO facilities. Much of his work is motivated by the requirement to dispose legacy and future nuclear wastes at ANSTO, as well as his passion to advance nuclear technologies by providing a better understanding of the waste properties.

GEN IV International Forum
Expertise | Collaboration | Excellence

Email: Dan Gregg: dgg@ansto.gov.au; Anton Peristyy: peristya@ansto.gov.au

Australian Government

ANSTO

ANSTO Synroc Technology: Solutions for the treatment of GenIV reactor wastes

18th February 2026

Dr Daniel Gregg

Dr Anton Peristyy

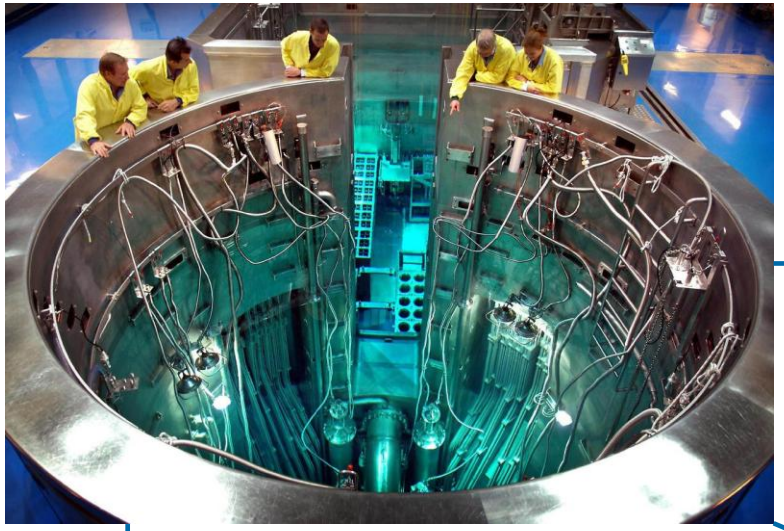
Science. Ingenuity. Sustainability.

What is ANSTO Synroc® technology

- What is ANSTO Synroc®?
  - Technology and Historical Context
- ANSTO Synroc® Waste Treatment Facility
  - Technology development and maturation
  - Treatment of Mo-99 production Wastes
- Future Application
  - Actinide wastes
  - Molten salt wastes
  - Iodine wastes
  - Inorganic exchange media wastes

Background to ANSTO

Reactor-Based Operations



OPAL Reactor

Neutron Scattering

Nuclear Medicine Manufacturing

Reactor-doped silicon

Non-Reactor Operations

Australian Synchrotron

Centre for Accelerator Science

ANSTO

Waste Treatment for Advanced Reactors

GLOBAL Legacy

Nuclear waste stockpiled pending a long-term solution

Innovative Reactors and Fuel Cycles
New and Problematic Waste Streams

Facilitate Public Acceptance
Feasible Treatment Strategies for ILW and HLW

GLOBAL Future

Waste management solutions are increasingly required

- Approval of new technology conditional on a waste plan ✓
- Lifecycle waste planning delivers long term benefits ✓
- Social acceptance and trust ✓
- Synroc Solutions ✓

ANSTO

Why use ANSTO Synroc® technology?

Inspired by nature

- Based on naturally-occurring, highly-durable mineral phases
- Locked up U, Th over geological timeframes

Substantial benefits

- High durability ✓
- Low disposal volumes ✓
- Suited for problematic wastes ✓
- Flexible modular technology ✓

ANSTO

- First of a kind Synroc Plant
- Mo-99 production waste

ANSTO

ANSTO Synroc® Technology – Development Timeline

1978 – Initial scientific publications concerning Synroc

1982 – "Atlanta Shoot Out" – Synroc technology selected 2nd behind vitrification for US defence wastes. Although Synroc was determined to be a better product, Vitrification was a more mature technology.

1983 – **ANSTO Synroc®** process technology moved from lab to a pilot plant.

1994 – Plutonium Immobilisation Project commences in collaboration with US DoE laboratories

1997 – US Record of Decision – Synroc wasteform and process designed by ANSTO in collaboration by US DoE laboratories selected for Plutonium immobilisation.

2005 – **ANSTO Synroc®** commence waste treatment design for US reprocessed naval reactor fuel (HLW)

2009 – US Record of Decision – HIP selected to treat US reprocessed naval reactor fuel (HLW)

2010 – **ANSTO Synroc®** commence wasteform design for Mo-99 production wastes

2012 – Australian Federal Government funding received to design and build **ANSTO Synroc®** Waste Treatment Facility

2017 – Construction commences of **ANSTO Synroc®** Waste Treatment Facility

2019 – **ANSTO Synroc®** Demonstration Plant fully integrated demonstration facility

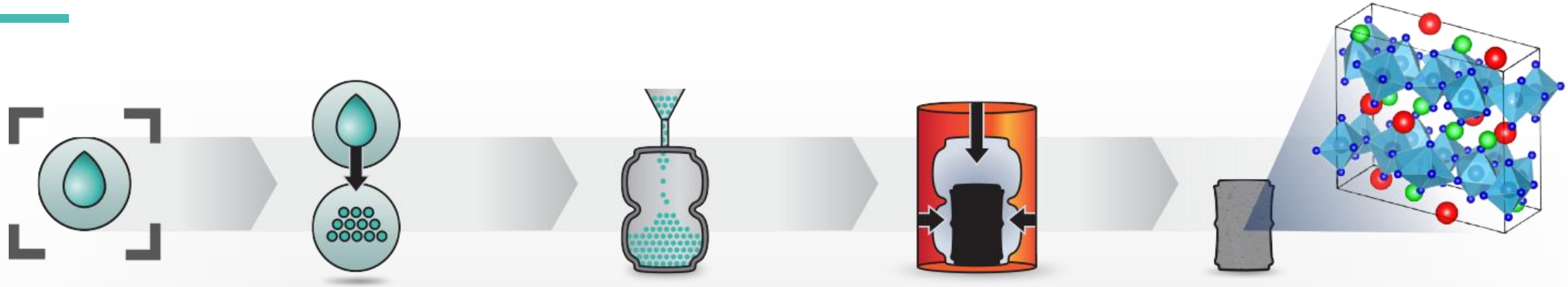
2025 – Cold Commissioning of **ANSTO Synroc®** Waste Treatment Facility Starts

2027 – Hot Commissioning of **ANSTO Synroc®** Waste Treatment Facility

Gregg et al. Synroc technology: Perspectives and current status. Journal of the American Ceramic Society, 103, 5424-5441, 2020

ANSTO

ANSTO Synroc® Technology



Decades of international study underpin Synroc and ceramic wasteforms

- Plutonium Immobilisation
- Refractory wastes
- Volatile wastes

Complementary to existing technologies such as vitrification

- Broad range of problematic wastes

ANSTO

ANSTO Synroc®

ILW & HLW

Pre-treatment

Liquid

Solid

Additives

Processing

HIP

Tailored Product

- Ceramic
- Glass-ceramic
- Glass
- Other composite

Synroc advantages

- Flexible & tailored
- High performance – reduced environmental risk
- Minimal disposal volumes – reduced lifecycle costs
- Disposal ready
- No secondary wastes
- Nuclear Material Accountancy

ANSTO

Innovative reactor & advanced fuel cycle wastes

ANSTO Synroc® technology well positioned for:

Advanced Reactor WASTES

Chemically exotic fuels & coolants

EXAMPLES

Fluoride wastes | Chloride salt wastes

Fuel Reprocessing WASTES

Highly mobile, volatile & long $t_{1/2}$

EXAMPLES

Iodine-129 | Technetium-99

Actinide WASTES

Fissile, nuclear material

EXAMPLES

Uranium | Plutonium

SMR WASTES

- Molten salt wastes
- Actinide wastes
- Advanced fuel wastes

Identification of principle wastes as designs evolve

↓

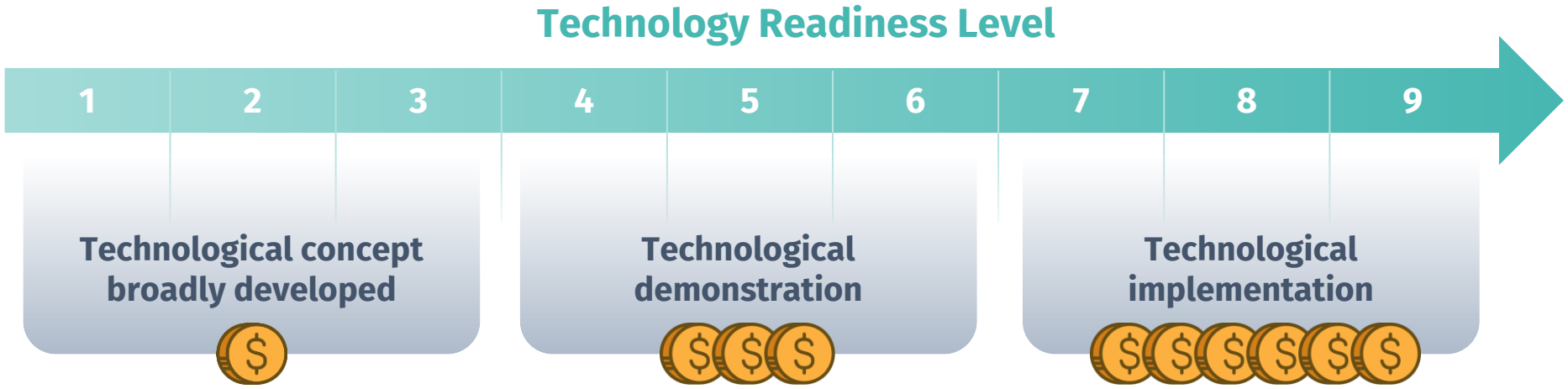
Advanced wasteform design

↓

Hot isostatic pressing technology

ANSTO

ANSTO Synroc® Technology Maturation



Achieved over the past 40 years

International collaborations

- Laboratory scale
- Mock-up demonstration

Achieved through Synroc Waste Treatment Facility

Further maturation requires

- Waste liability and organisational driver
- External funding
- Project for implementation

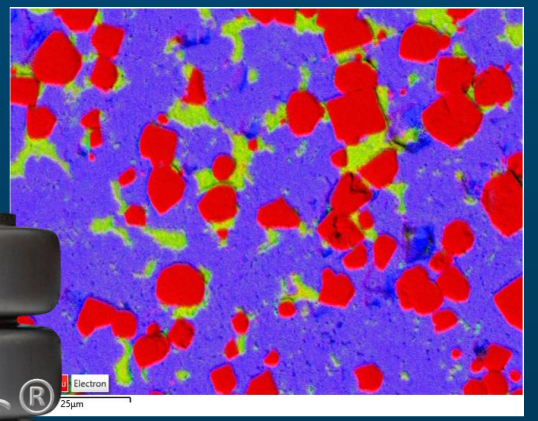
Synroc Waste Treatment Facility

- Opportunity to mature ANSTO Synroc® Technology
- Technology translation and maturation programme as opposed to technology procurement or simple civil build
- Substantial investment in technology development and personnel development

ANSTO

Laboratory Scale Development – Wasteform

- Waste characterisation methodologies
- Wasteform conceptual design and development
- Wasteform performance
- Develop engineering data to support process and demonstrate wasteform performance

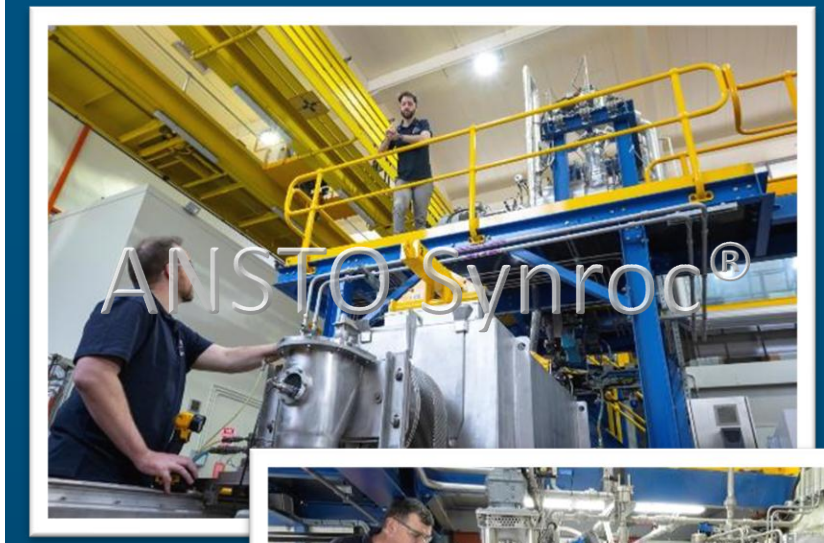


Laboratory Scale Research & Development

ANSTO

Process development and Demonstration (mid TRL)

- Risk mitigation strategy to validate, verify and **demonstrate integrated process design**
- Engineering development and system architecture
- Develop Quality Assurance framework for final wasteform product
- Process validation and **training**
- Develop and test **maintenance strategies**
- Increase Technological maturity
- Develop Engineering Talent



ANSTO

Synroc Waste Treatment Facility

Technology Implementation

Build

Process contained within building

Large hot cell structure

Building externally delivered

Fit out

ANSTO responsible for managing fit out

Substantial in-house expertise

Trusted sub-contractor network

Commission

Extensive verification and validation programme

Operational readiness – transition to operations

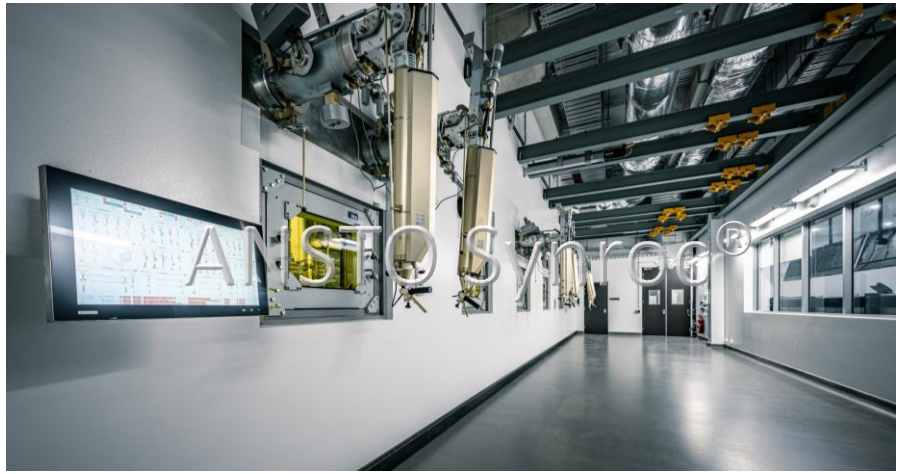
Implement quality management systems

Commissioning Programme

- Designed to address First of a kind integration risks
- Prove and accept technology
- Test and validation operational and maintenance approaches
- Provide data to support safety case and regulatory submissions
- Demonstrate wasteform (product) meets performance specification

ANSTO

Synroc Waste Treatment Facility



Waste Characterisation

Waste Characterisation Program

Waste acceptance into the Synroc waste treatment facility

Input information for the treatment process: additive design

Quality assurance of the final wasteform

Program requirements

Method development & Implementation

Radiological assessments & sampling

Waste Characterisation

ANSTO

Characterisation for waste acceptance into SWTF

Sampling program

- Impact of sampling system parameters
- Repeatability
- Sampling confidence
- Resourcing and operator doses
- Sample stability, transport and storage

Analysis of the active material

- Requirements of the characterisation program
- Method validation using actual samples
- Assessment of whether the capped tank with waste meets specification for treatment

Reporting

- Feedback to the sampling and measurements methods
- Updating the source term and radiological assessments
- Updating risk assessments and notification to the regulator

ANSTO

Characterization for treatment process control

Waste Stability Assessment

- Quarterly measurements
- Long term changes in waste chemistry
- Precipitation of insoluble components
- Reactions with atmospheric CO_2

Routine Sampling

- Analyse each batch for acceptance into the SWTF plant
- Characterisation data used to generate quality documentation

Additive Design

- Characterisation data used to calculate the composition of the additive required to produce quality assured product

ANSTO

Characterisation for waste acceptance into repository

Manufacturing process feedback

- Characterisation of the wasteform (glass) produced by SWTP

Quality assured wasteform

- Verify product composition
- Verify glass phase is formed
- Verify product performance

Critical to disposal nuclides

- Radiological properties of the product
- DTM nuclides
- Critical to disposal nuclides

ANSTO

Important qualities of a wasteform for actinides

Extremely long half-lives

Radiologically and chemically-toxic

Fissile isotopes that require criticality control and safeguards measures

Economic Drivers

Maximise the waste loading

Environmental Drivers

Maximise chemical durability

Criticality Control

During processing and in the repository via incorporation of neutron poisons

Safeguarding

Proliferation *resistant* wasteform, Radiation barriers and physical security

Processibility

Incorporation of chemical and physical impurities

Social and Political Acceptance

Public & institutional acceptance

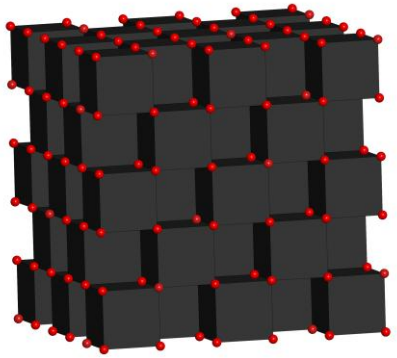
Benefits of ANSTO Synroc® technology

- Access to advanced ceramic and glass-ceramic wasteforms
- Tailored ceramic phases based on natural analogues
  - Durable
  - Criticality control
- Large dense ceramic monoliths with controlled grain size
- Allows nuclear accounting in line with safeguards requirements
- Challenging uranium recovery and/or downblending

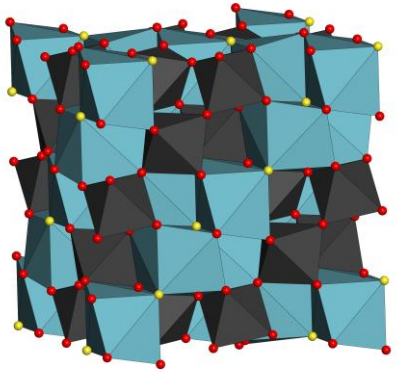
ANSTO

Wasteform Design Strategy

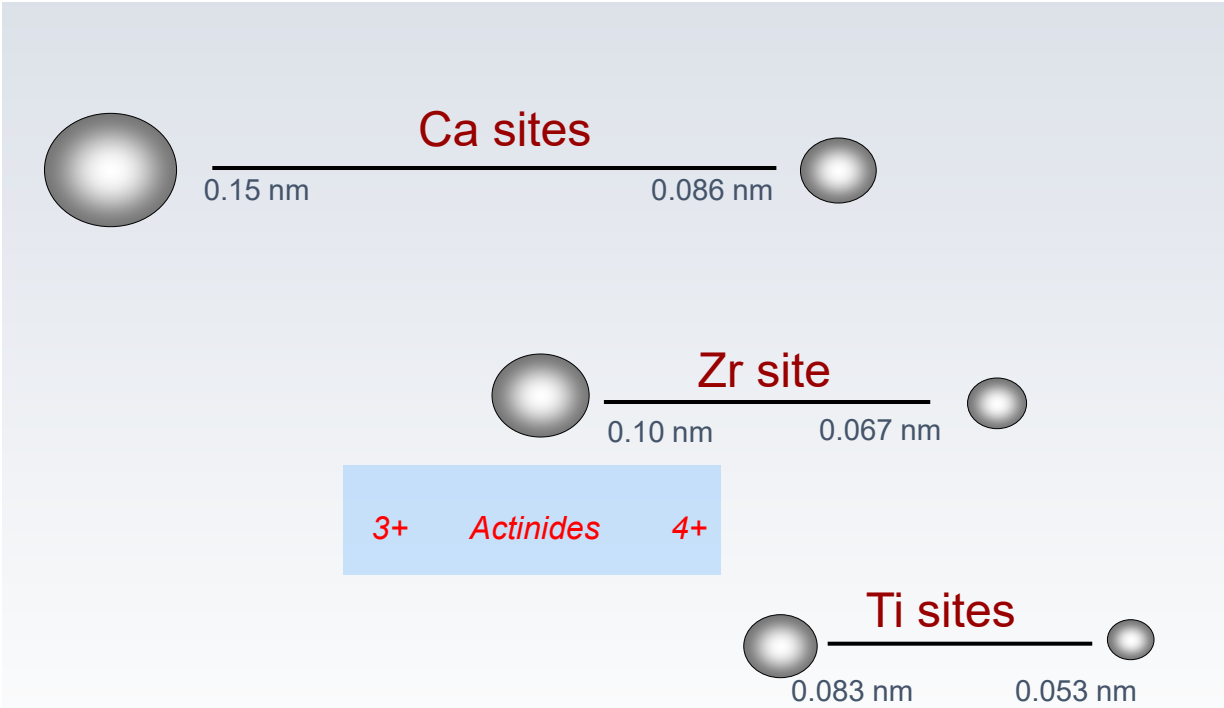
Radionuclides enter into solid solution in the mineral phases as a result of appropriate formulation design and processing conditions



Zirconolite
$CaZrTi_2O_7$



Pyrochlore
$CaUTi_2O_7$

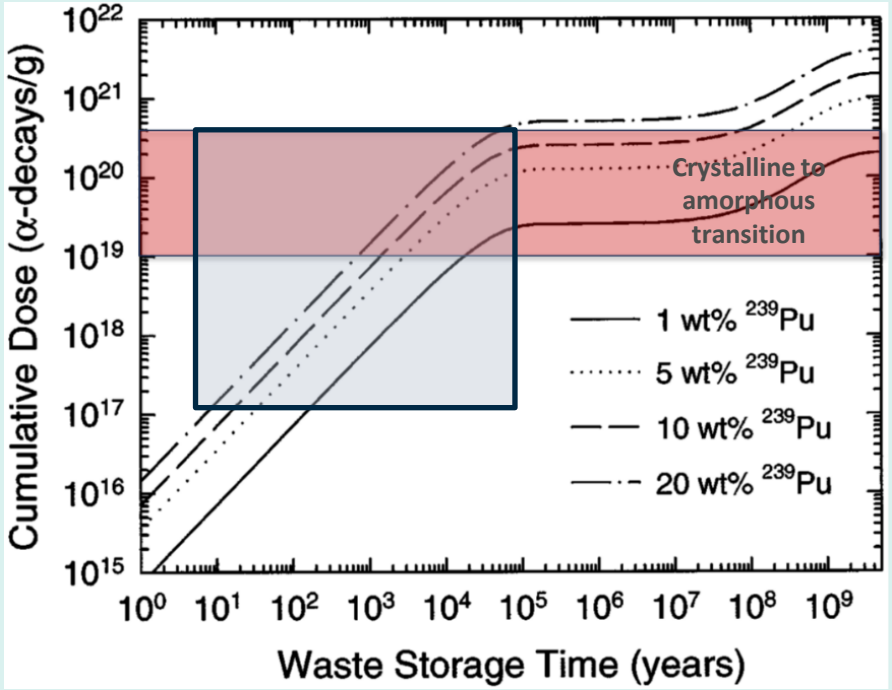


ANSTO

Wasteform Design Strategy

Why use natural analogues

- Natural analogues are long-term natural experiments
- Snapshots in time of the result of alteration and α-decay processes over millions to billions of years
- Complementary information to laboratory experiments:
  - Inform the disposal safety case and model development (technical)
  - **Social acceptance through 'digestible' evidence** (non-technical)
- Limitations:
  - Initial conditions may not be known precisely
  - More variable chemistries



Adapted from Weber Journal of Materials Research 13 (1998) 1434-1484

ANSTO

Research to deliver treatment solutions for ANSTO wastes

Synroc technology for Current & Legacy Actinide Wastes

ANSTO FOCUS: **LEU wastes from current and previous Mo-99 production at ANSTO**

Chemical/Processing flexibility (Glass) Exceptional durability (Ceramic)

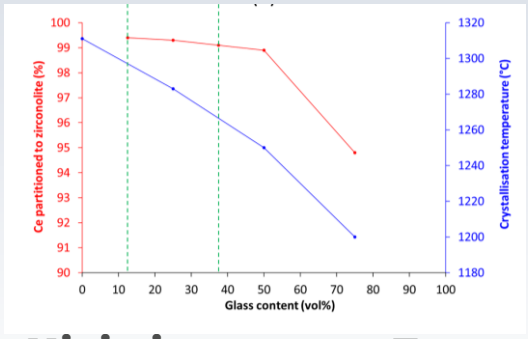
GLASS-CERAMIC DESIGN

Glass content required for wasteform (FPs) and engineering benefits

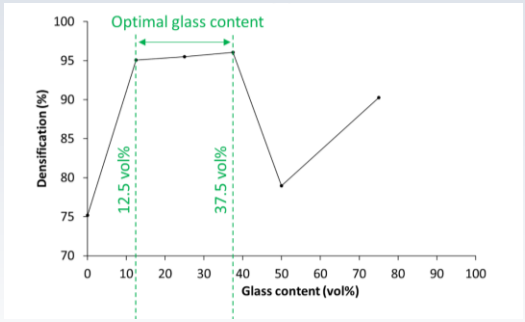
Key waste elements:

92 **U** Uranium

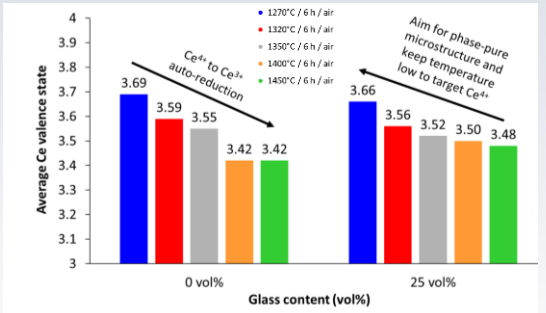
FPs Fission Products



Minimise process Temp. Maximise partitioning



Maximise Density



Control Actinide Valence

High waste loadings achievable (~40 wt.% U)
Possibility for down-blend if required

~30 Litres Waste

~ 5 L
Disposable Synroc

ANSTO

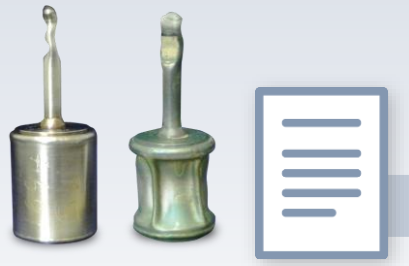
ANSTO Synroc® technology for fluoride salt wastes

Corrosive fluoride salt coolants

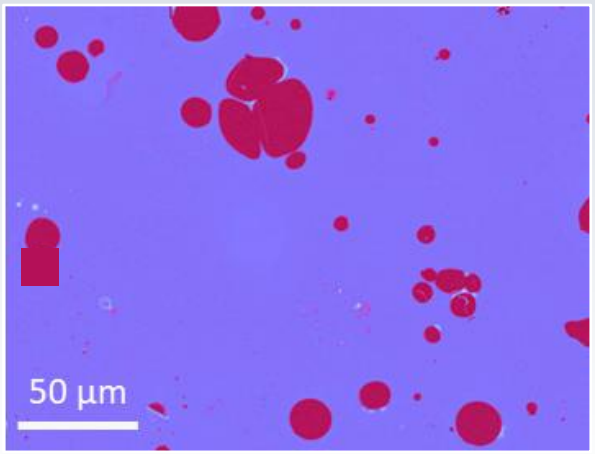
Radiotoxic, highly chemically reactive, volatile and corrosive

Novel glass-ceramic for fluoride salts.
High waste loading ~20 wt.%
Tailored for salt components

F partitioned to mineral phase
Alkalis and FPs partitioned to glass



Demonstrated on the laboratory scale



Feasible Solution
Highly stable mineral phases containing fluorine

Gregg et al., J. Am. Ceram. Soc. 103, 5454 (2020)

Benefits of ANSTO Synroc® technology

- Prevention of volatile loss into the off-gas system
- Access to advanced ceramic and glass-ceramic wasteforms
- Large dense ceramic monoliths with controlled grain size
- Allows nuclear accounting in line with safeguards requirements

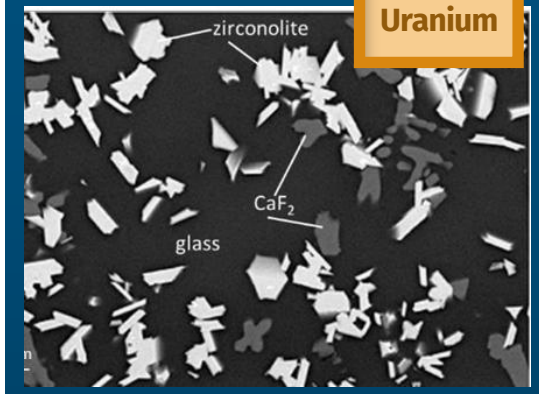
ANSTO

Scale-up Demonstration

- Addition of compatible phases (e.g., zircon, ZrO_2, spinel, zirconolite)
- Demonstrated at 25 kg scale
- Product is
  - Dense
  - Homogeneous within HIP canister
- Product has good aqueous durability
- No detrimental HIP canister interaction

Extension to include actinides

92
U
Uranium



- Additional phase(s) to incorporate actinides
- Neutron poisons for criticality control
- Other salt components, e.g., Zr

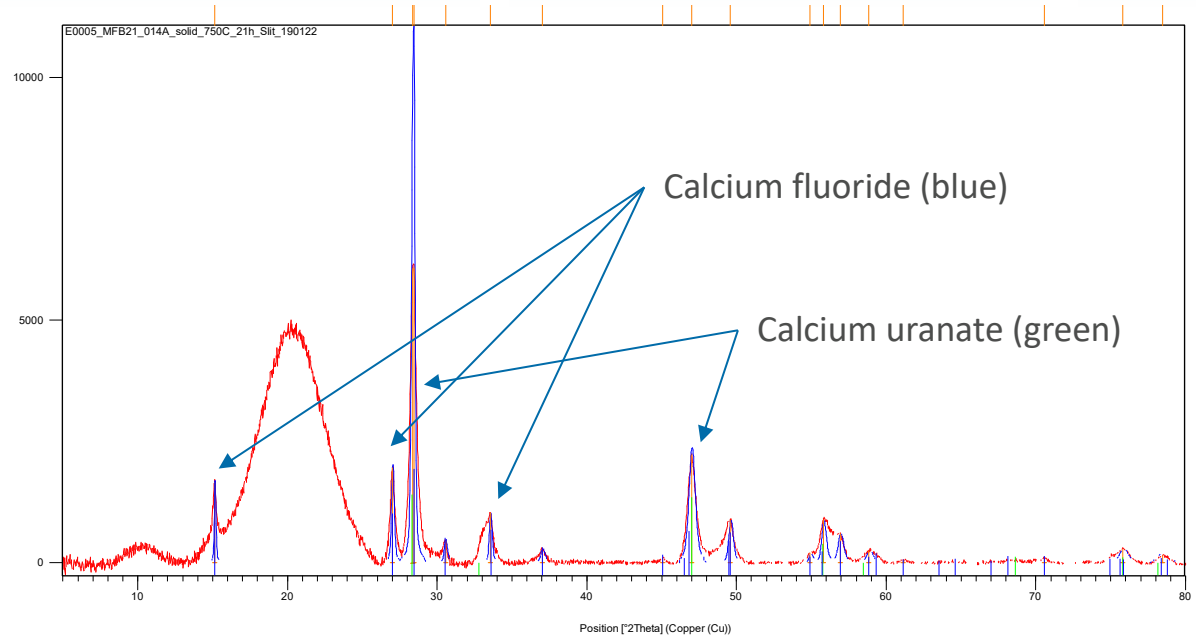
ANSTO

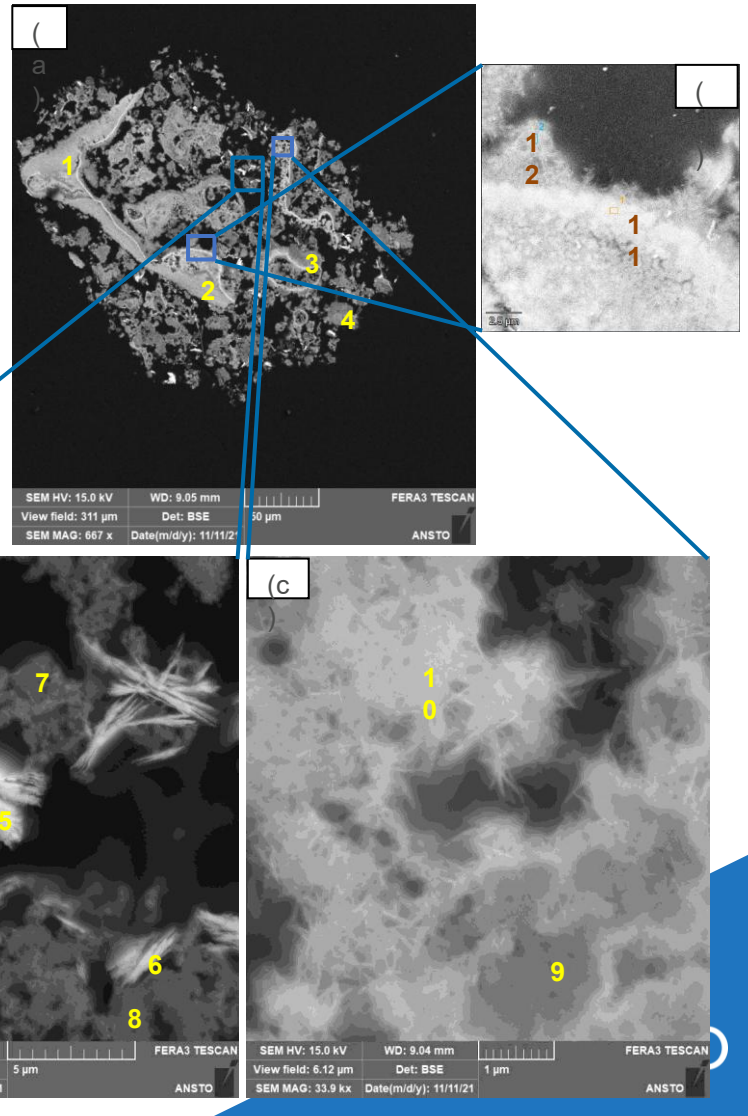
Characterisation of stabilized waste containing U and F Process quality assurance

Legacy
UF_6 traps

Chemically Stabilised
Nuclear material

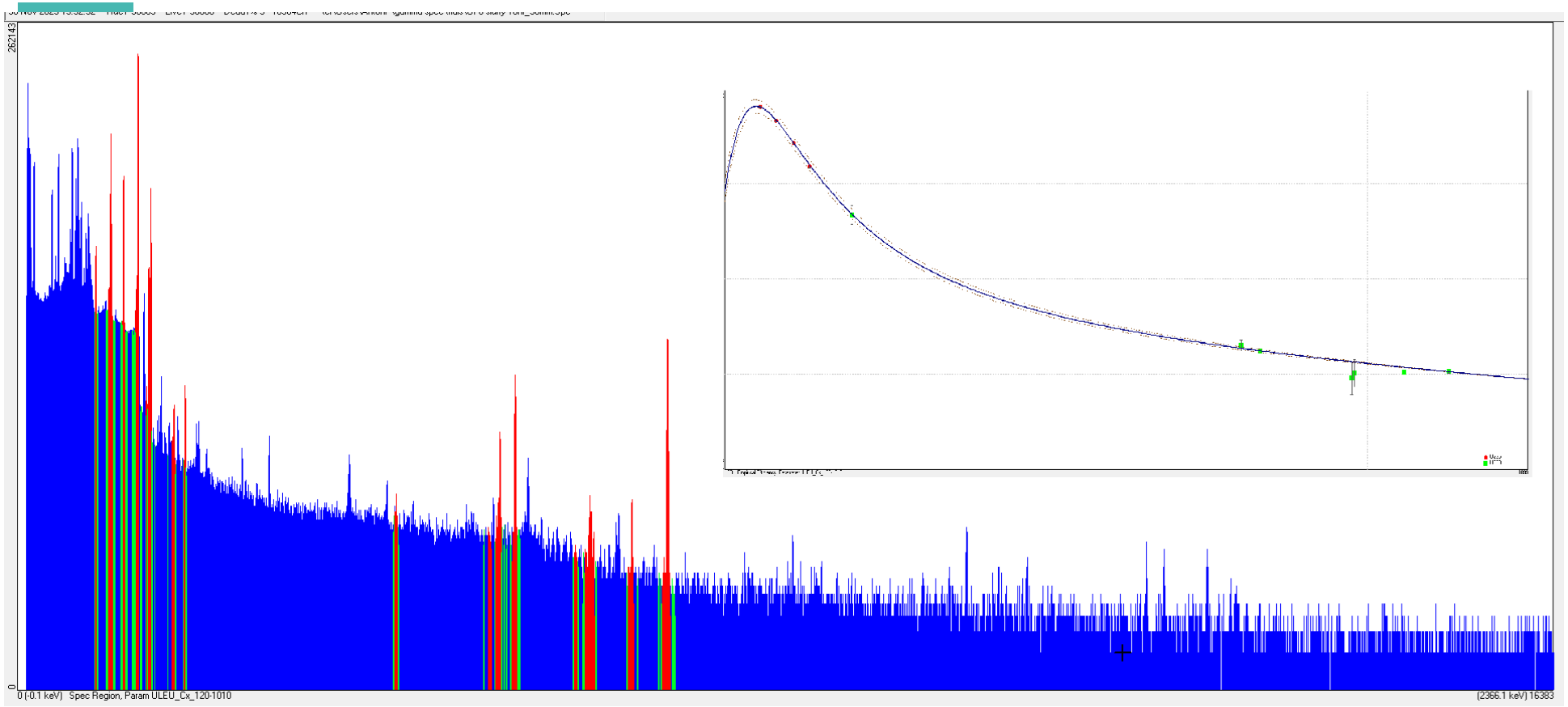
~1.1 Litre / Litre
Disposable Synroc





Characterisation of stabilized waste containing U and F

Regulatory and Safeguards requirements



	% w/w	% RSD
U-234	0.084	2.9
U-235	8.6	2.1
U-238	91.3	0.2

ANSTO

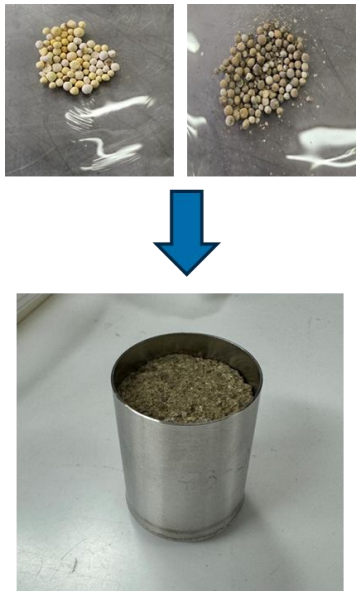
ANSTO Synroc® technology for iodine wastes

- **Highly mobile, biological activity, volatility and long half-life (^{129}I)**
- **Consolidation of iodine capture materials (become waste streams)**
  - ***From gaseous phase or from solutions***

HIP of Ag-sodalite: $Ag_8(AlSiO_4)_2I_2$
- Consolidation to a durable I-bearing ceramic

HIP of glass bonded sodalite
- Improved densification using glass composite

HIP of Ag mordenite
- Zeolite materials to remove iodine from nuclear waste streams and then consolidation
- Reduce handling and processing



J. Nucl. Mater., 480, 177-181 (2016) / J. Nucl. Mater., 591, 154938 (2024)

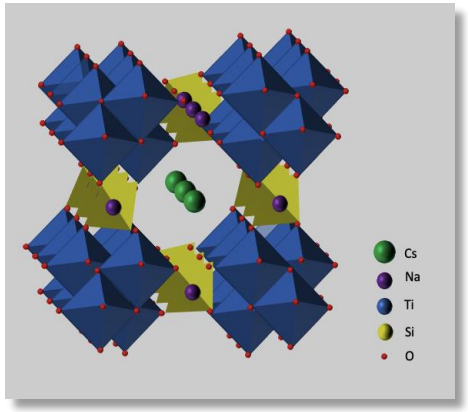
Benefits of ANSTO Synroc® technology

- Prevention of volatile loss into the off-gas system
- Access to advanced ceramic and glass-ceramic wasteforms
- Tailored ceramic phases based on natural analogues
- Large dense ceramic monoliths

ANSTO

Advanced Wasteforms for the Immobilization of Cs-Loaded IONSIV Wastes

Wasteform design for Cs-loaded IONSIV



Cs-loaded IONSIV
(Cs Capture)

Synroc Technology

Highly stable mineral phases to lock up radioactive Cs

Ion-exchange media to decontaminate liquid wastes become waste themselves

Novel advanced wasteform solution with high performance and low volume

Key waste elements:

Bahman Rokh et al. Environ. Sci. Technol. 2025, 59, 16, 7948-7959

Benefits of ANSTO Synroc® technology

- Prevention of volatile Cs loss into the off-gas system
- Access to advanced ceramic and glass-ceramic wasteforms
- Tailored ceramic phases based on natural analogues
- Substantial volume reduction (>60%)
- Dense and durable product

ANSTO

GenIV Waste Characterisation MSR

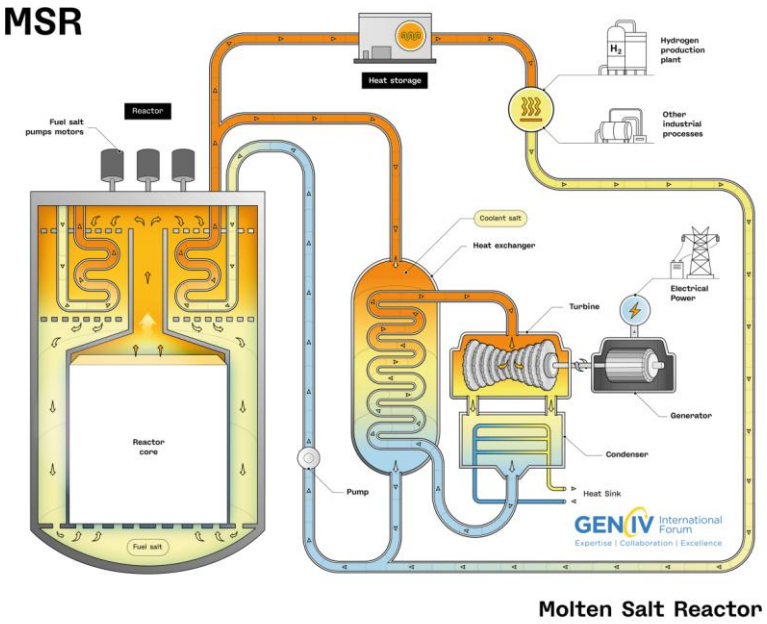
- **Waste stream example: Spent fluoride salt**

Chemical Characterisation:

- Li, Na, K
- Be
- Zr
- Corrosion products

Radiological Characterisation:

- Minor actinides
- Fission products (critical to disposal
- H-3



Molten Salt Reactor

ANSTO

GenIV Waste Characterisation GFR and VHTR

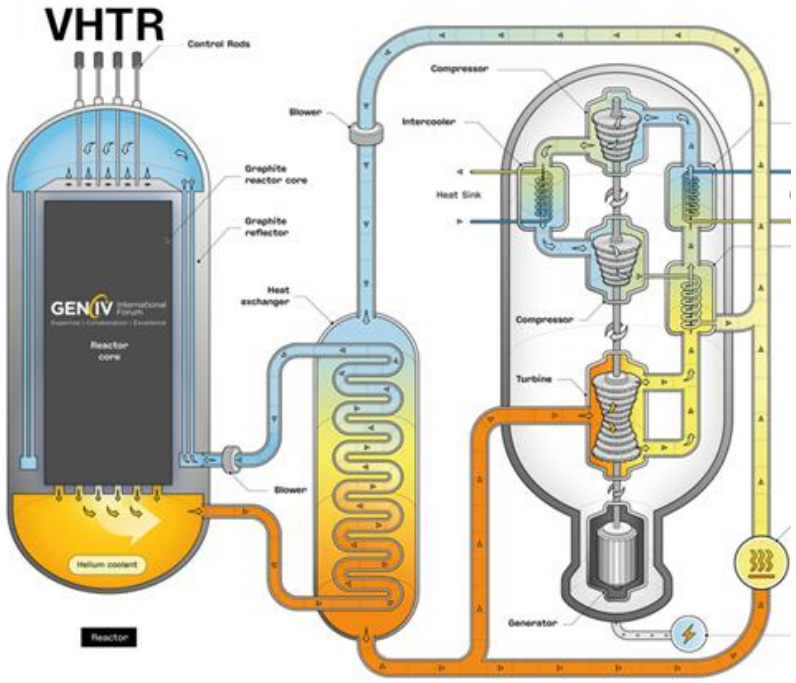
- **Waste stream example: Gas filters/sorbents**

Chemical Characterisation:

- Toxic metals (incl. Ag)
- I speciation: I^- vs IO_3^-
- Impurities (Cl, S, P)

Radiological Characterisation:

- I-129
- Other fission products (critical to disposal)
- Gross alpha/beta



Very-High-Temperature Reactor

ANSTO

GenIV Waste Characterisation SFR and LFR

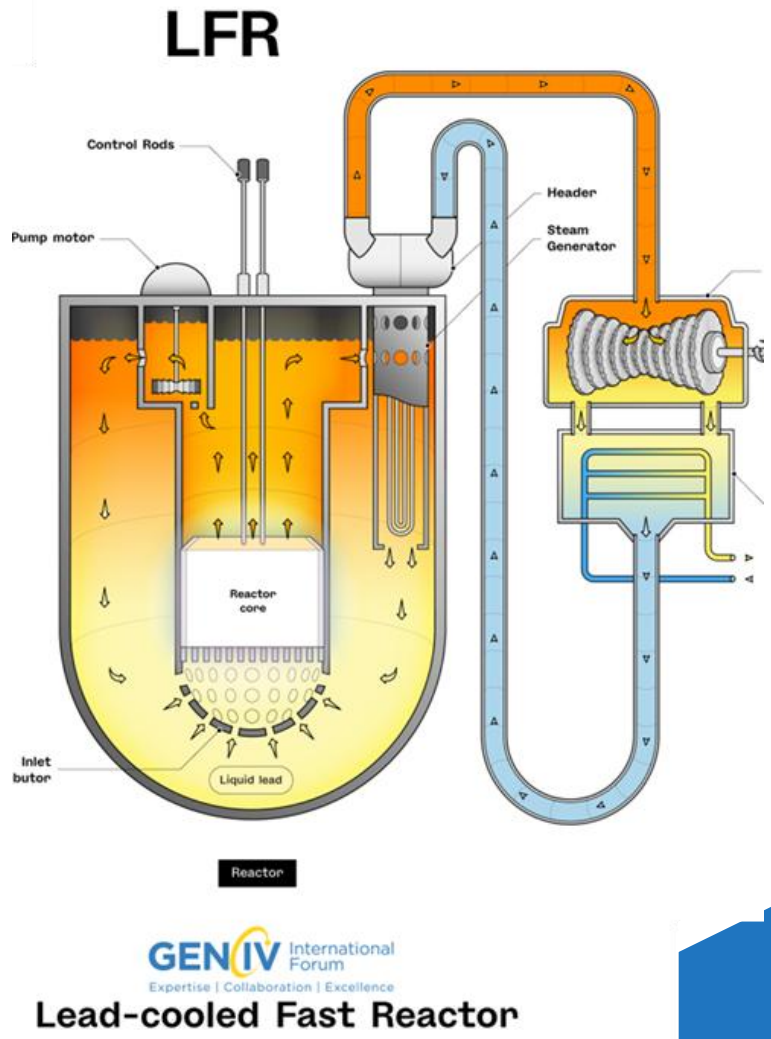
- Waste stream example: Pb-Bi coolant

Chemical Characterisation:

- Bulk composition
- Corrosion products (Fe, Mn, Cr)

Radiological Characterisation:

- Pb-205, Pb-210
- Bi-208
- Actinide content



ANSTO

GenIV Waste Characterisation SCWR

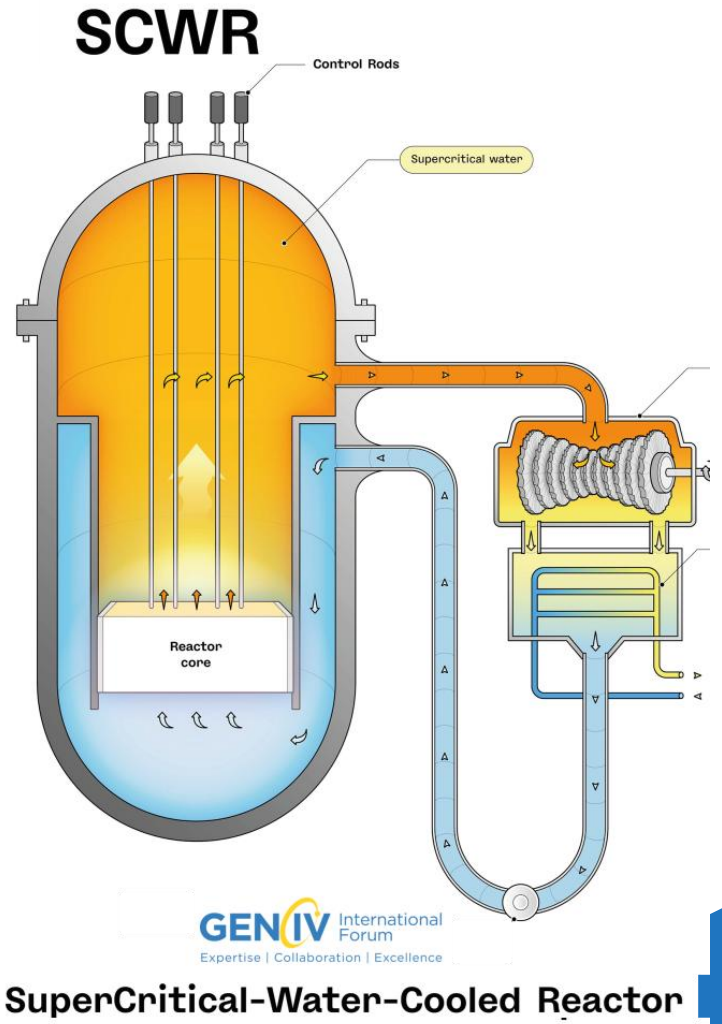
- **Waste stream example: Spent MOX fuel**

Chemical Characterisation:

- U, Pu, Th
- Cladding components: Zr, Cr
- H, D and T content

Radiological Characterisation:

- U and Pu isotopic composition
- Minor actinides
- Fission products
- Volatile radionuclides

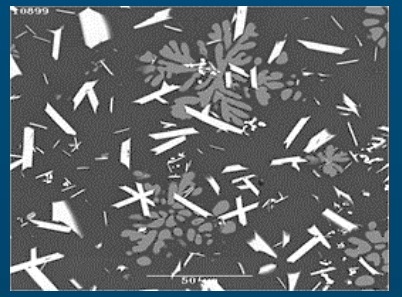


ANSTO

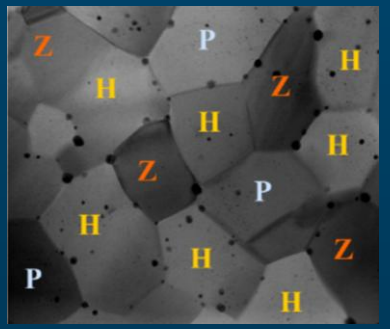
Summary

- Innovative Reactors & Fuel Cycles will Produce New and Problematic Waste Streams
  - Chemically exotic fuels / coolants
  - Radiotoxic, highly chemically reactive, volatile and corrosive
- Additional **Challenge**:
  - Identification of principle (and probable) wastes as designs continue to evolve
- **Opportunity** to realize longer term efficiencies and savings by considering waste treatment early
- Provide **high feasibility solutions** and develop a systematic technology maturity approach
- ANSTO Synroc® technology can play a significant role

Glass



Glass-ceramic



Ceramic

ANSTO

The Team

Amanda Abboud, Ghazaleh Bahman Rokh, Paola Baratcabal, Richard Barton, Sharon Bay, Olivia Beck, Bruce Begg, Ben Bigrigg, Bryan Blayney, Sophie Bossa, Richard Briggs, Kyle Brown, Ronny Calderon Vicencio, Aravin Chellappah, Patrick Day, Pranesh Dayal, Steve Deen, Michael Deura, Christian Deura, Kate Dwight, Nazli Eslamirad, Rifat Farzana, Nic Fradellin, Dan Gregg, Alex Hallock, Elaria Hanna, Gus Hatem, Matt Hillocks, Rohan Holmes, Blagica Joleska, William Jones, Will Kaploun, Amol Kothawade, Iveta Kurlapski, Cynthia Leung, Joshua Lucas, Irene Martin, Mile Miladinovski, Hien Nguyen, Anton Peristyy, Jonathan Pitt, Jamie Skuse, Kim Stokeld, Phillip Sutton, Erfan Taheri, Gerry Triani, Brian Turner, Lili Wang, Catherine Welsh

Find out more

Discover more about ANSTO Synroc®

Connect on social

Australian Government

ANSTO

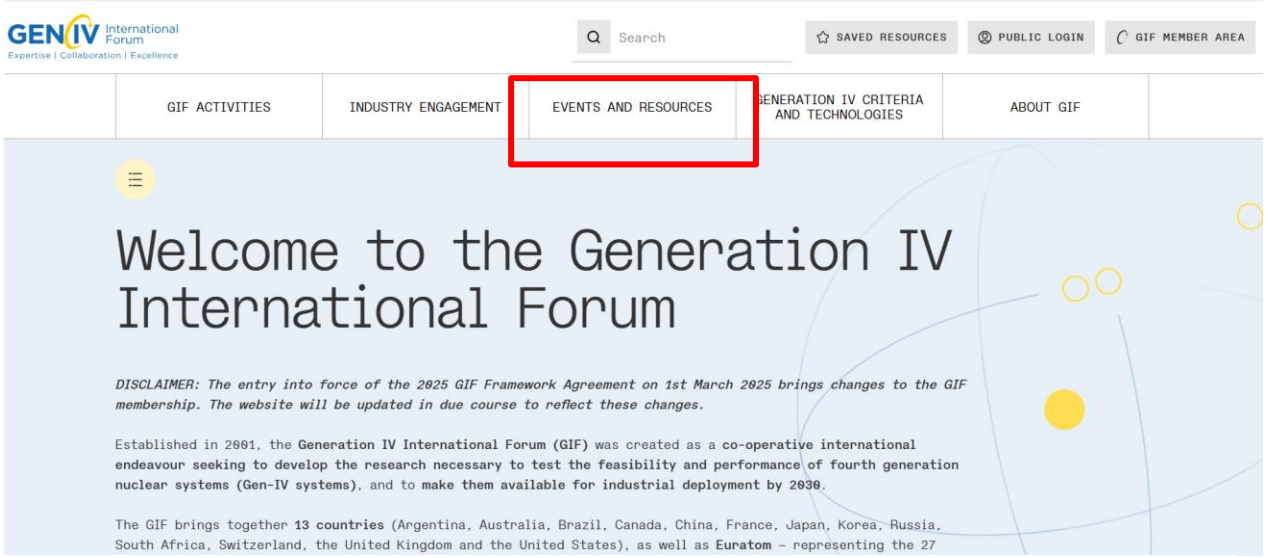
Upcoming Webinars

Date	Title	Presenter
18 March 2026	Overview of the various UK NNL activities supporting advanced reactor systems and their related fuel cycles	Dr. Mike Edmonson, Dr. Seddon Atkinson, Dr. Nassia Tzelepi, UK National Nuclear Laboratory, United Kingdom
29 April 2026	Advances in Monitoring Techniques for Molten Salt Reactor and Fuel Cycle	Prof. Sungyeol Choi, Seoul National University, ROK
05 May 2026	Joint GIF/IAEA Webinar: AI advances in the nuclear energy sector	Moderators: Alexei Miassoedov, IAEA; Patricia Paviet, PNNL, USA

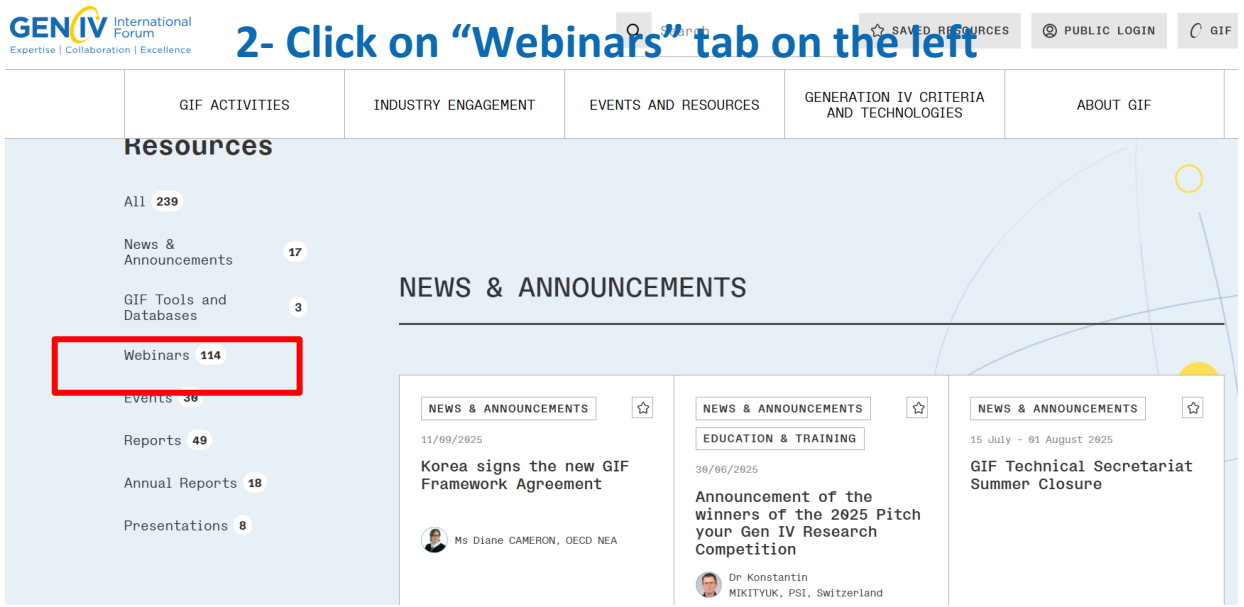
GEN IV International Forum

How to find the recorded GIF webinars – www.gen-4.org

1- Click on “Events and Resources Tab



2- Click on “Webinars” tab on the left



3- Click on “HERE” to see all the webinars

Or

4-Use the Year and Resource tag and click on Filter