Australian Government

ANSTO



Research Impact Report 2026

Science. Ingenuity. Sustainability.

ANSTO

Research Impact Report 2026

Highlights from the period 2022—2025.

The Report was produced in November 2026.

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Introductory Statement from Board Chair

It is my privilege to present the second edition of the **ANSTO Research Impact Report.**

This report demonstrates how Australia's sustained investment in nuclear science, technology and research infrastructure is delivering practical benefits for the nation. Across health, industry, the environment, national security and emerging technologies, ANSTO's people and capabilities are helping address complex challenges and translate research into outcomes.

ANSTO operates nationally significant science infrastructure that is unique in Australia and recognised internationally. These facilities provide researchers from universities, industry and government with access to specialised techniques, supported by ANSTO's expertise.

Just under 80 case studies in this report highlight the breadth of this capability. They demonstrate how collaboration across the research sector, industry, government and international partners extends the reach of Australia's science infrastructure and delivers national benefit.

ANSTO's research is guided by its responsibilities under the **Australian Nuclear Science and Technology Organisation Act 1987**, the objectives of our Corporate Plan and the Australian Government's national science and research priorities.

While representing only a fraction of the research undertaken at ANSTO, these examples reflect our broader commitment to scientific excellence, collaboration and practical impact.

Together, they demonstrate the value of maintaining an enduring nuclear science and technology capability to support Australia's health, resilience, productivity and sovereign capability.



Michael Quigley

Statement from Group Executive, Nuclear Science and Technology

Research and development is fundamental to Australia's health, prosperity and resilience. Nuclear science and technology provides a unique R&D capability, with carbon dating, isotope tracing, neutron scattering, accelerator and radiation technologies to name a few.

This compendium of case studies captures scientific investigation and outcomes using nuclear science and technology over a three-year period since the release of the previous **Research Impact Report.**

These outcomes help deliver practical national benefit through healthier communities, a more sustainable environment and enhanced prosperity enabled by technological innovation.

During this period, ANSTO's research remained focused on priorities that have been identified by the Australian Government and major national challenges, including climate change, aging population and sustainability. This alignment is reflected in the case studies in this collection.

ANSTO's distinctive and integrated capability brings together specialist infrastructure, expertise and partnerships to understand matter at scales from the atomic to the macroscopic, harness radiation for beneficial purposes, and translate nuclear science and technology into practical outcomes.

A key impact area is improving health, particularly in the use of medical radioisotopes for prospective diagnosis and treatment of disease and the beneficial impacts of radiation. There are some very promising developments as captured by new approaches to breast cancer diagnosis and advanced radiation therapies.

With capabilities to measure isotopes in the environment, we are able to provide a better understanding of groundwater reserves, understand the movement of climate, secure food sources and date irreplaceable Aboriginal rock art.

By applying our knowledge, infrastructure and experience in the handling of advanced materials used in the nuclear industry, we bring progress in operations, safety and security for our own operations and beyond.

And ANSTO's capabilities in the processing of critical minerals have been used by industry to support Government goals as shown in this Report.

Ultimately, excellent research comes down to excellent people. The quality of the research presented in this Report is testament to the collective experience and dedication of our people at ANSTO. Most of the case studies in this document also reflect the collaborative nature of modern scientific research. Those collaborations, including our ability to leverage outcomes through the prodigious use of our research infrastructure, make ANSTO a beneficiary of the principle that, no matter how big and clever your organisation is, most of the smartest people work elsewhere. We are grateful to all our partners and collaborators for joining us in using the power of nuclear science and technology to make progress.



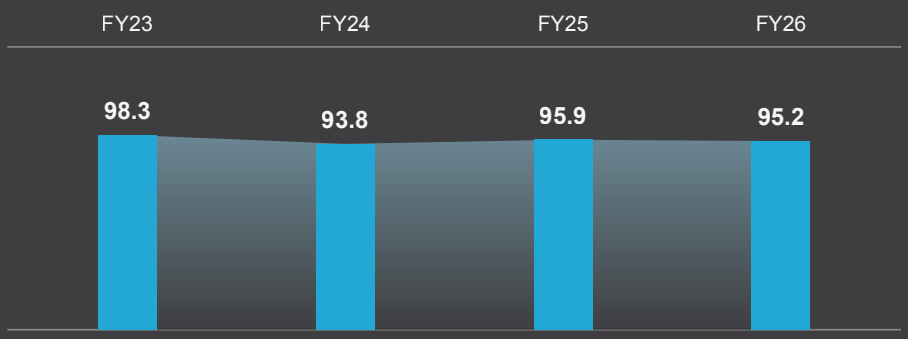
Prof Andrew Peele

Australian Synchrotron (AS)

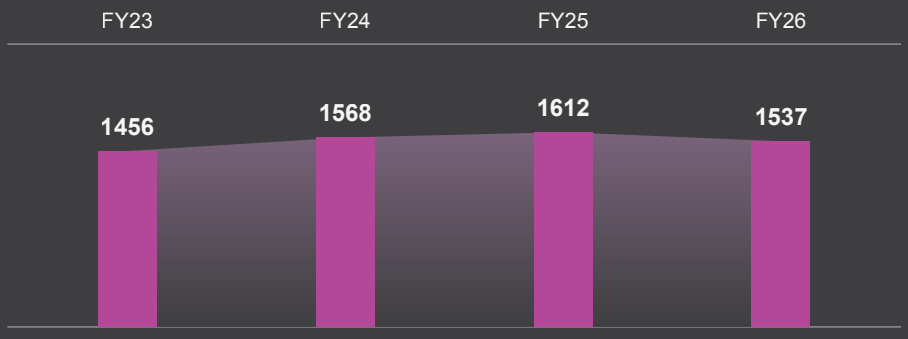
Utilisation and demand

The Australian Synchrotron utilisation performance is measured by the number of hours delivered out of the scheduled number of hours available

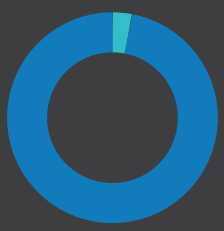
AS utilisation and demand



AS approved proposals



Internal and external users



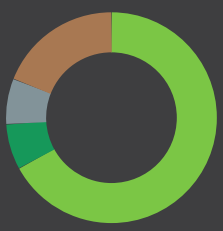
Internal	3%
External	97%

Users by sector



Aus universities / research organisations	81%
Industry	2%
Int universities and research institutes	19%

User access mode



Merit Access	67%
Paid Access	7%
Discretionary	7%
Commissioning	19%

AS user profile Numbers are averaged for four financial years (FY23-FY26) from a total of 4158 unique users (based on user visits to the Australian Synchrotron)

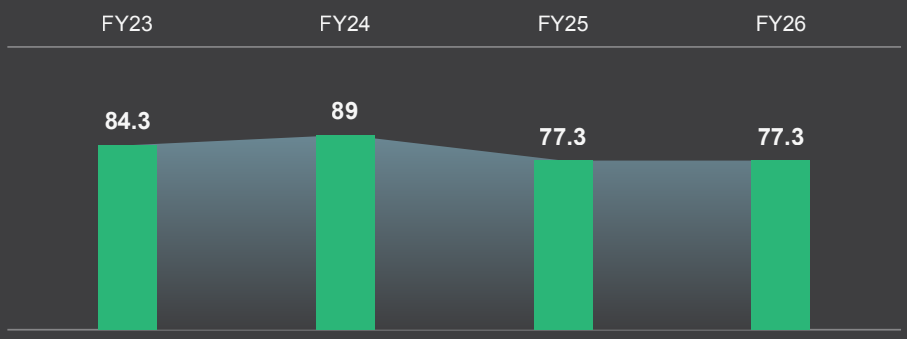
AS user access mode distribution averaged for four financial years (FY23-FY26).

Australian Centre for Neutron Scattering (ACNS)

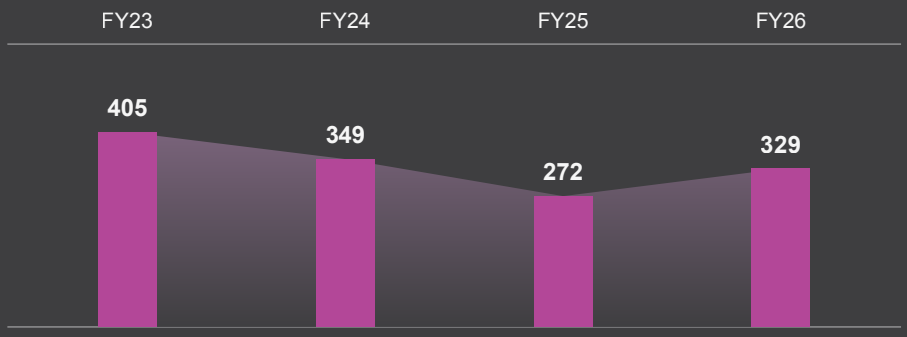
Utilisation and demand

ACNS utilisation is measured by the number of actual operating days out of scheduled operating time.

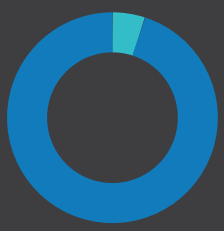
ACNS utilisation and demand



ACNS approved proposals



Internal and external users



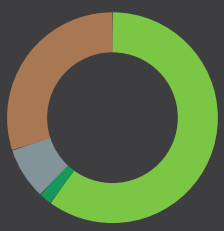
Internal	5%
External	95%

Users by sector



Aus universities / research organisations	45%
Industry	1%
Int universities and research institutes	54%

User access mode



Merit Access	60%
Paid Access	2%
Discretionary	8%
Commissioning	30%

ACNS user profile Numbers are averaged for four financial years (FY23-FY26) from a total of 2094 unique users (based on usage and user visits to the Australian Centre for Neutron Scattering)

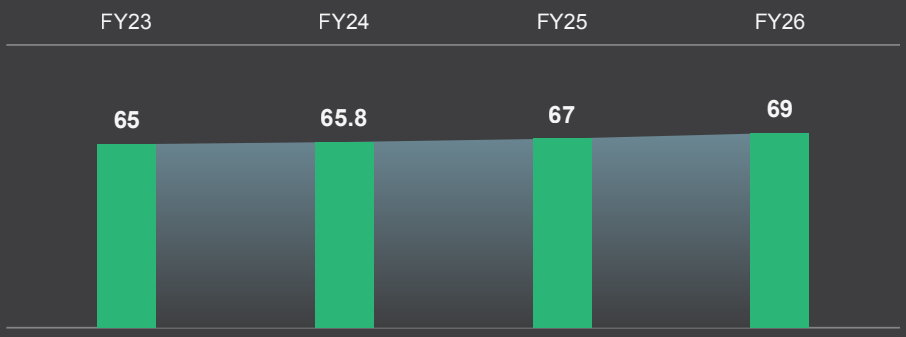
ACNS user access mode distribution averaged for four financial years (FY23-FY26) for neutron beam instruments days utilised across the suite of instruments available. Planned maintenance and testing has also been included.

Centre for
Accelerator Science (CAS)

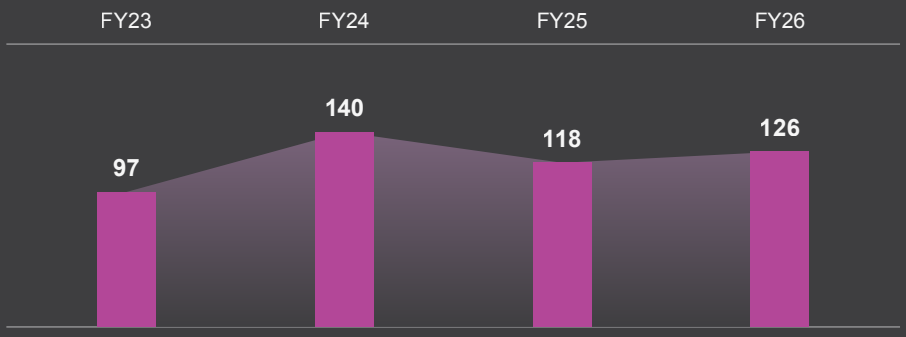
Utilisation and demand

The CAS utilisation is measured by the number of days operating for the user program against the number of days avilable. The number of days avilable for the user program is the number of accelerator days (250 business days per year per accelerator) minus the number of days used for planned an unplanned maintenance and system upgrades.

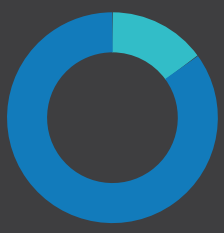
CAS utilisation and demand



CAS approved proposals



Internal and external users



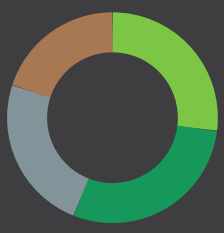
Internal	15%
External	85%

Users by sector



Aus universities / research organisations	68%
Industry	11%
Int universities and research institutes	21%

User access mode



Merit Access	27%
Paid Access	29%
Discretionary	24%
Commissioning	20%

CAS user profile Numbers are averaged for four financial years (FY23-FY26) from a total of 790 unique users from approved proposals

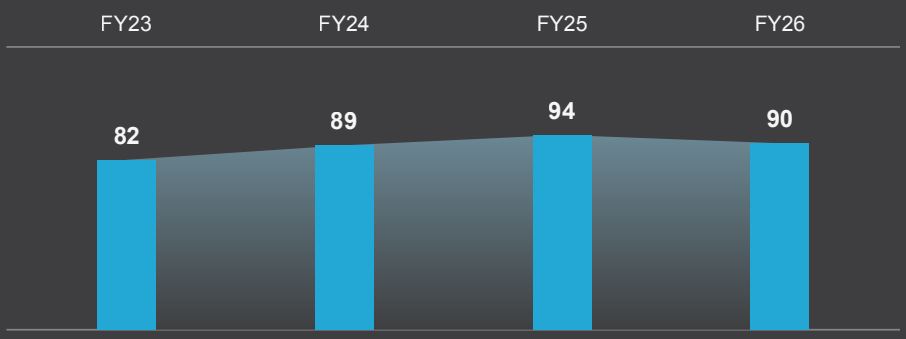
CAS user access mode distribution averaged for four financial years (FY23-FY26) .

National Deuteration Facility (NDF)

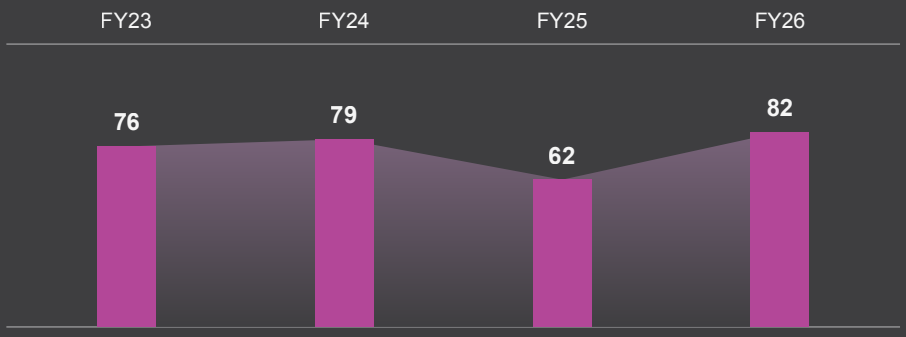
Utilisation and demand

The National Deuteration Facility user performance is measured by the percentage of the National Deuteration Facility production capacity utilised by the approved user demand.

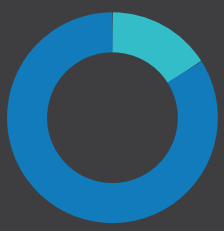
NDF utilisation and demand



NDF approved proposals



Internal and external users



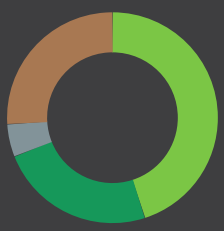
Internal	16%
External	84%

Users by sector



Aus universities / research organisations	66%
Industry	3%
Int universities and research institutes	31%

User access mode



Merit Access	45%
Paid Access	24%
Discretionary	5%
Commissioning	26%

NDF user profile Numbers are averaged for four financial years (FY23-FY26) from a total of 653 unique users who accessed the National Deuteration Facility (completed and ongoing proposals).

NDF user access mode distribution averaged for four financial years (FY23-FY26) for approved proposals.



Health

Nuclear science and technology can deliver better health outcomes

ANSTO undertakes and supports research that benefits human health. That research develops new knowledge and technologies for diagnosis and treatment, and strengthens expertise and infrastructure, supporting domestic production and timely and equitable access to life-saving radiopharmaceuticals for Australians.

ANSTO has supported the development and production of radioisotopes for applications in nuclear medicine since the 1960s. Our scientists work with clinicians and industry partners to advance radioisotope production and develop radiopharmaceuticals for nuclear imaging and therapeutic applications, building the evidence needed for clinical use.

With expertise in how radiation interacts with biology, ANSTO research enhances detection and diagnosis of disease and the development of new, more effective therapies with fewer side effects.

This includes developing and evaluating approaches that link diagnosis with targeted treatment (theranostics), developing personalised radiation treatments guided by imaging, dosimetry and biological response, and improving nuclear medicine production processes.

A therapy that kills invisible cancer cells

THE CHALLENGE

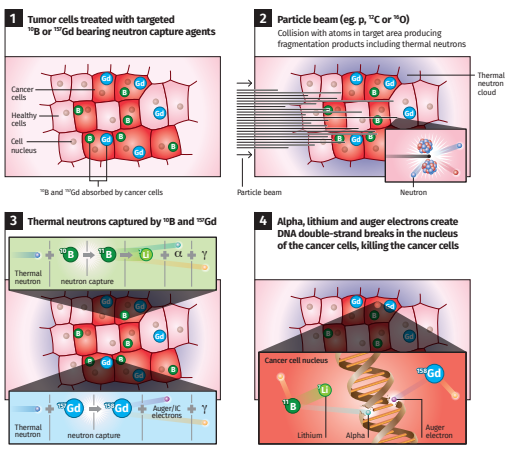
Glioblastoma, the most common aggressive brain cancer, kills most patients within fifteen months of diagnosis. For children with diffuse intrinsic pontine glioma, a brainstem cancer, survival is closer to twelve. These tumours resist treatment not because radiation lacks power but because the cancer has already spread beyond what scans can show and beams can safely target. Irradiating the invisible margins means destroying healthy brain; sparing them means leaving disease behind. Every advance in beam precision sharpens this dilemma rather than resolving it. What these patients need is a therapy that reaches the cells no one can see.

THE SOLUTION

NCEPT, Neutron Capture Enhanced Particle Therapy, turns the treatment itself into a second weapon. As a proton or carbon ion beam passes through tissue, nuclear collisions shed neutrons that spread through the surrounding anatomy. Before treatment, the patient receives a tumour-seeking drug carrying boron or gadolinium, which concentrates inside cancer cells, including the invisible infiltrates beyond the beam. When those atoms capture the passing neutrons, each releases a burst of radiation shorter than the width of a single cell, killing the cancer cell from within while sparing its neighbours. In 2024, experiments with human glioblastoma cells at Japan's heavy ion therapy facility delivered the first experimental proof. Adding the capture drugs during helium and carbon irradiation increased cancer cell killing three to five times, and cells outside the beam entirely, reached only by the neutrons, were killed as well. That out-of-field effect is exactly the capability conventional radiotherapy lacks.

THE IMPACT

A purpose-built detector, BeNEdiCTE, has since shown the neutron capture signal can be monitored in real time during treatment, a prerequisite for any clinical trial, and animal studies have confirmed significant delays in tumour growth. Two patents protect the approach. In 2024, ANSTO won a $1.62 million Medical Research Future Fund grant under the Australian Brain Cancer Mission, its first as lead institution, to complete the translational chain: validated drug candidates, treatment planning and clinician-approved protocols. The timing is deliberate. Australia's first particle therapy centres are now being built, and NCEPT is being made ready to meet them.



Australian Research Priority or Futures Made in Australia Framework

- Supporting healthy and thriving communities

ANSTO strategic priority

- Health

ANSTO capability/instrument

GATRI Gamma Irradiation Facility
Neutron Activation Analysis
ANSTO High performance Computational Infrastructure

Collaborators/clients

- University of Wollongong
- University of Technology Sydney
- The University of Sydney
- Politecnico di Milano, Italy
- Quantum Science and Technology, Japan (HIMAC)

ANSTO contributors

- Nicholas Howell
- Dr Frederic Sierro
- Dr Klaudiusz Jakobowski
- Dr Chris Dobie
- Dr Ryan Middleton
- Dr Mitra Safavi-Naeini
- Australian Centre for Neutron Scattering

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Image:
How NCEPT works: boron and gadolinium drugs load into cancer cells (1); the treating beam sheds neutrons (2) which the drugs capture (3), breaking the cancer cell's DNA (4). Adapted from Howell et al. (2024).

Reprinted under Creative Commons License 4.0. https://creativecommons.org/licenses/by-nc-nd/4.0/. Howell *et al., International Journal of Radiation Oncology, Biology, Physics* (2024).

Accelerating the purification of nuclear medicine with rapid screening of separation materials

THE CHALLENGE

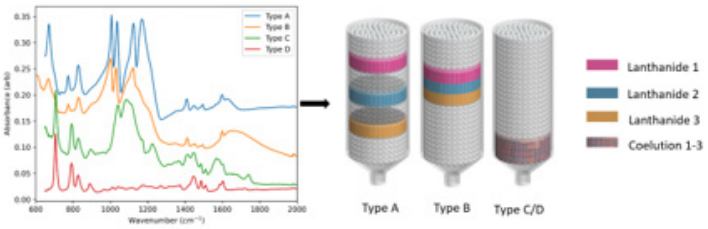
The efficient separation of radionuclides of interest and chemically similar elements, such as the lanthanides or actinides is critical for nuclear medicine, waste management and advanced materials. However, identifying suitable materials or separation systems is typically slow, labour-intensive, resource-heavy and requires extensive chromatographic testing. These challenges create bottlenecks in developing new radiochemical processes and limit the capacity to rapidly optimise separations for emerging isotopes and applications.

THE SOLUTION

The study developed a rapid, analytical screening approach to evaluate materials and predict their performance in radionuclide separations without full testing. By combining spectroscopic characterisation with physical parameters such as resin structure and composition, the method enables the classification of materials based on functional groups and binding behaviour. This solution allows researchers to correlate chemical structure with separation performance and identify the materials most suitable for resolving closely related elements. The methodology significantly reduces experimental burden by replacing time-consuming separation trials with faster predictive analysis. The study demonstrated that specific structural features, such as. functional groups and polymer composition strongly influence separation efficiency. It provides a practical framework for selecting and optimising materials in radiochemical and analytical workflow.

THE IMPACT

This work enables faster, lower-cost development of radiochemical separations to accelerate research and the production of medically important isotopes. By improving efficiency and reducing waste, it supports scalable and sustainable isotope processing. The findings also advance the scientific understanding of structure–function relationships in separation materials with benefits for nuclear medicine, environmental monitoring and nuclear applications.



Australian Research Priority or Futures Made in Australia Framework

- Supporting healthy and thriving communities

ANSTO strategic priority

- Improve the health of Australians by supporting access to current and future nuclear technologies
- Australia's source of Nuclear expertise

ANSTO capability/instrument

Radiochemistry and separations expertise
FTIR spectroscopy and analytical chemistry platforms

Collaborators/clients

- Radiochemistry and separations expertise
- FTIR spectroscopy and analytical chemistry platforms

ANSTO contributors

- Dr Jessica Veliscek-Carolan
- Dr Paul Pellegrini
- Dr Leena Burgess
- Ms Ilkay Chironi
- Dr Flora Mansour

Paper DOI

doi.org/10.1016/j.microc.2025.116078

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Image:
FTIR for predictive chromatography.

Reprinted under Creative Commons License 4.0. https://creativecommons.org/licenses/by/4.0/. Veliscek-Cardon *et al., Microchemical Journal* (2025).

ANSTO developed targeted gene knockout model used in Alzheimer's disease research

THE CHALLENGE

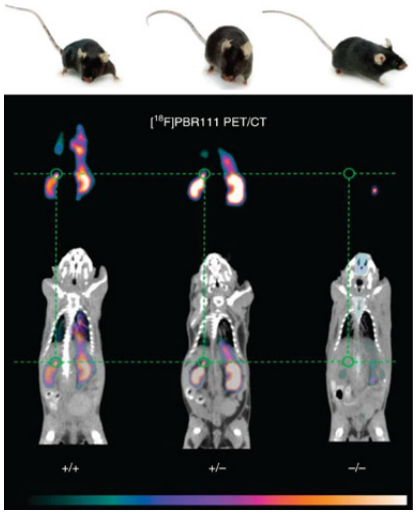
Clinical and preclinical studies have shown that levels of a mitochondrial translator protein (TSPO) expressed in most tissues and cell types, increase during neuroinflammatory conditions, such as Alzheimer's disease and in various cancers. This finding makes TSPO an important theranostic target. However, there is a need for a reliable tool to assess the specificity and selectivity of TSPO-targeting agents from small-molecule compounds to antibodies. This tool would help researchers gain a better understanding the physiological and pathological roles involving TSPO. Previously health researchers at ANSTO developed a TSPO knockout mouse model that completely lacked TSPO expression.

THE SOLUTION

The ANSTO team led the research and developed the TSPO knockout mouse model using gene-targeting technology. This work showed that mice lacking TSPO were healthy and viable and overturned the long-held belief that TSPO is essential for life and that its deletion would cause embryonic death. TSPO knockout mice have become a valuable tool for both basic research and the development of theranostics. The model was used to confirm the specificity of ANSTO-developed TSPO imaging agents. The model has supported research in neurodegenerative disorders, including Alzheimer's disease, as well as studies of lipid metabolism and other physiological processes through international collaborations.

THE IMPACT

TSPO knockout mice were used to uncover a novel mechanism by which diazepam affects brain function. The study showed that diazepam, a widely used anti-anxiety and sedative medication, can alter nerves in the brain and impair cognitive function through its interaction with TSPO rather than by classical receptors. The TSPO knockout mice were also used more recently in another collaborative study that demonstrated that the deletion of TSPO had a protective effect in Alzheimer's disease. The study found that TSPO knockout prevented the early loss of nerve fibres originating in the brain stem and projecting to the brain's smell centre, the olfactory bulb, a symptom also seen in the early stages of Alzheimer's disease.



Australian Research Priority or Futures Made in Australia Framework

- Supporting health and thriving communities

ANSTO strategic priority

- Improve the health of Australians by supporting access to current and future nuclear technologies

ANSTO capability/instrument

Radiobiology
Vivarium facility
PET/CT

Collaborators/clients

- Professor Richard Banati, University of Sydney
- Professor Jochen Herms, Ludwig-Maximilians-Universität, Germany
- Dr Lars Paeger, German Centre for Neurodegenerative Diseases, Germany

ANSTO contributors

- Professor Guo-Jun Liu
- Dr Ryan Middleton

Paper DOI

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doi.org/10.1038/s41593-022-01013-9

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Image:
Wild type (Tspo+/+), heterozygous (Tspo+/–) and knockout (Tspo–/–) mice are imaged with PET/CT using the radioligand [18F]PBR111.

Reprinted under Creative Commons License 4.0. https://creativecommons.org/licenses/by/4.0/. Banati *et al., Nature Communications* (2014).

Building skills in nuclear medicine imaging

THE CHALLENGE

Research into nuclear medicines requires specialist skills in preparing radioactive tracers, working with laboratory animals and using imaging equipment. Practical training helps researchers bring these skills together and gain experience with the methods needed for future studies

THE SOLUTION

ANSTO brought together staff from its radioisotope, radiochemistry, biology and imaging teams for practical training using established tracer compounds.

The work used PET and SPECT scanners, which detect radiation from tracers to show where they are distributed in the body. Staff tested imaging procedures in healthy laboratory animals and mice used to model prostate cancer, gaining experience in tracer preparation, scanning and image review.

The activities included imaging with lutetium-177 and terbium-161 produced in ANSTO's OPAL reactor. They connected the work of teams responsible for producing radioisotopes, preparing tracers, caring for animals and acquiring images.

THE IMPACT

The immediate contribution was practical training for ANSTO staff across the steps involved in an imaging study. The work also produced a collection of reference images that can support further training and the planning of subsequent experiments. By developing staff experience with these methods and facilities, ANSTO is building the skills needed to undertake future research into nuclear medicines.

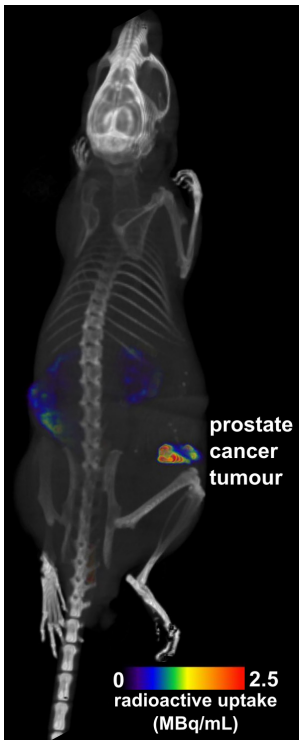

Image:
A scan of a mouse used to model prostate cancer, following administration of a tracer labelled with terbium-161 produced in ANSTO's OPAL reactor. The colours show where the radioactive tracer was detected.

Australian Research Priority or Futures Made in Australia Framework

- Supporting healthy and thriving communities

ANSTO strategic priority

- Improve the health of Australians by supporting access to current and future nuclear technologies

ANSTO capability/instrument

Preclinical PET/CT and SPECT/CT
Radiopharmaceutical production
Vivarium

ANSTO contributors

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- Michelle Amesbury
- Phillip Janowicz
- Andrew Arthur
- Dr Loan Le
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- Dr Daniel Rivinoja
- Dr Giancarlo Pascali
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- Bethany Apperley
- Dr Lidia Matesic
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- Dr Leila Hill
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Confirming that implants can stand up to advanced cancer therapy

THE CHALLENGE

Doctors increasingly treat cancer with proton therapy, a precise form of radiotherapy that releases most of its energy where the radiation beam stops—ideally inside the tumour. A growing number of patients have orthopaedic or dental implants made from a strong medical-grade plastic the body tolerates well. When an implant lies in the beam's path, that peak energy can land inside the plastic itself. It was not known if this weakens implants over a course of treatment, because earlier studies tested X-rays and electrons rather than protons. Clinicians needed direct evidence before they could rule out damage to implants.

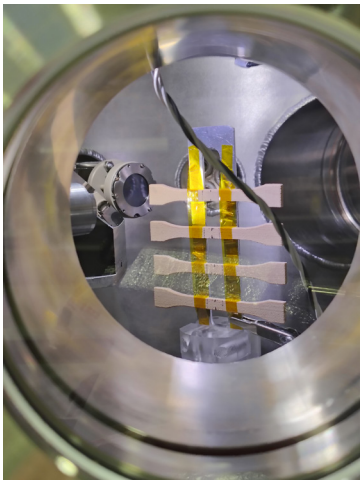
THE SOLUTION

Researchers from ANSTO, the University of Sydney and the Liverpool & Macarthur Cancer Therapy Centre wanted confirmation of the impact on implants. Using an accelerator technique, the team tuned a proton beam so it released its peak energy inside samples of polymers of interest, the worst case scenario. Doses of radiation ranged from a single therapy session to levels thousands of times higher. The team then stretched and bent the samples to measure their strength, and used spectroscopy techniques to check for changes in structure. The materials held firm. Strength and internal structure showed no significant change at any dose. The only changes detected were microscopic marks on the sample surfaces. The study concluded that proton therapy does not degrade implant plastics, even at doses far beyond clinical treatment.

THE IMPACT

Clinicians can now plan proton therapy for patients with implants knowing the treatment will not weaken them. This evidence supports treatment decisions in orthopaedics, dentistry and head and neck reconstruction, and removes a barrier to the wider use of polymer implants in particle therapy. The results give implant designers and clinicians a firmer basis for choosing polymer materials. ANSTO's accelerators can test how medical materials cope with radiation before those materials are exposed in patients. The team plans to extend the work to the heavier particles used in next-generation cancer treatments.





Australian Research Priority or Futures Made in Australia Framework

- Supporting healthy and thriving communities

ANSTO strategic priority

- Deliver on Australia's priorities for the benefit of people, industry and the environment

ANSTO capability/instrument

Centre for Accelerator Science
Heavy Ion Nuclear Microprobe beamline

Collaborators/clients

- University of Sydney
- Liverpool & Macarthur Cancer Therapy Centre
- Dr Georgio Katsifis
- Linda Losurdo (PhD candidate)

ANSTO contributors

- Dr Stefania Peracchi
- Dr Ryan Drury
- Dr Zeljko Pastuovic

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Image:
Left: PhD candidate Linda Losurdo and Dr Georgio Katsifis with their PEEK test pieces and film before irradiation on the SIRIUS beamline at ANSTO. Right: an array of four dog-bone-shaped test pieces mounted inside the SIRIUS vacuum chamber.

Enabling early breast cancer detection

THE CHALLENGE

Measurement of certain organic molecules in blood, known as lipids, can be used to diagnose conditions such as breast cancer. In practice however, the accurate quantification of lipids is difficult due to a lack of reference standards.

THE SOLUTION

The National Deuteration Facility (NDF) replaced some hydrogen atoms in lipids with their stable isotope deuterium. These deuterated lipids, in high purity form, are considered the gold standard for quantitative measurement of lipids in blood samples.

Since 2022, the facility has supplied BCAL Diagnostics with custom deuterated lipids as stable isotope internal standards, enabling the accurate quantification of lipid biomarkers relevant to breast cancer.

In March 2025, BCAL Diagnostics announced their first product, BREASTEST plus™, a blood test for breast cancer, was available at the Sydney Breast Clinic. A nationwide rollout has since commenced.

THE IMPACT

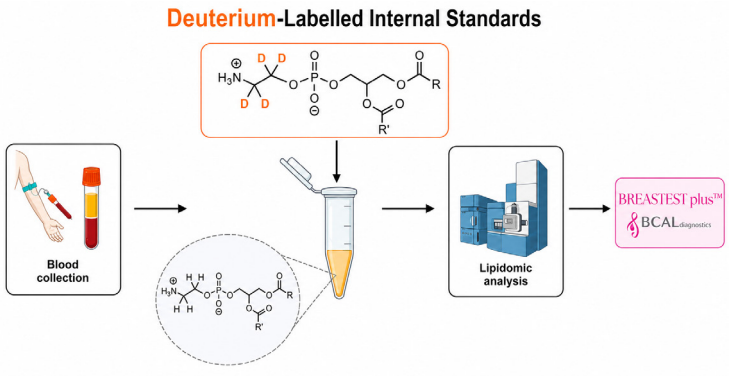
BREASTEST plus™ complements mammography testing and improves cancer detection in women with dense breast tissue (40–50% of Australian women).

An earlier diagnosis improves survival for the 1 in 7 Australian women who will develop breast cancer.

Deuterium-labelled standards ensure high diagnostic accuracy and reduce false positives and false negatives.

Economic modelling shows potential savings of $40–80 million per 100,000 women screened because of fewer unnecessary biopsies, earlier-stage treatment, and reduced loss of productivity.

"Access to ANSTO's specialist capability in synthesising deuterium-labelled lipid standards has been invaluable in the development and clinical implementation of BREASTEST plus™, enabling reliable measurement of lipid biomarkers in complex biological samples. This capability remains important as BCAL Diagnostics continues to develop and validate future products." - ***Mark David, Director, Mass Spectrometry, BCAL Diagnostics***



Australian Research Priority or Futures Made in Australia Framework

- Supporting healthy and thriving communities

ANSTO strategic priority

- Deliver on Australian priorities for the benefit of people, industry and environment

ANSTO capability/instrument

National Deuteration Facility
Deuteration

Collaborators/clients

- BCAL Diagnostics

ANSTO contributors

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- Dr Carl Recsei
- Dr Tamim Darwish

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Enabling research on an advanced cancer therapy in Australia

THE CHALLENGE

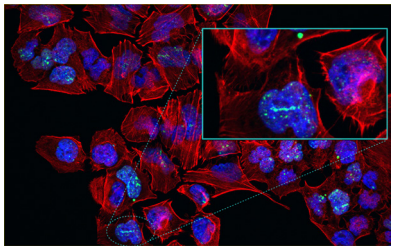
Neutron capture therapy (NCT) allows the cellular-level targeting of tumours while sparing healthy tissue. Chemicals containing specific stable isotopes that are selectively taken up by tumour cells release densely ionising, cytotoxic radiation when struck by neutrons. New accelerator technologies are making NCT increasingly accessible worldwide, and Australia risks falling behind. Despite operating reactor-based neutron sources for decades, ANSTO has had none configured for biological experimentation since MOATA ceased operation in 1995. Live cell irradiation demands precise dose characterisation, the distribution of radiation, and the maintenance of physiological and aseptic conditions, which are not available at the OPAL multi-purpose reactor. Researchers must travel overseas for this type of experiment at significant cost and with logistical constraints limiting productivity.

THE SOLUTION

By reconfiguring the pre-existing neutron tomography instrument Dingo at ANSTO, the team established a reliable, reproducible and cost-effective neutron radiobiology platform, which is the first of its kind in Australia. It enables systematic and repeated experimentation with NCT compounds under conditions that are directly relevant to clinical application. The methodology removes the barrier requiring Australian researchers to travel overseas for access to neutron radiobiology facilities. By pairing a validated simulation model of the neutron beam and spectrum with a live cell irradiation setup, researchers can plan and predict dose conditions computationally before using the instrument. It can confirm the biological effect of neutron capture directly in irradiated cells by flow cytometry and immunocytochemistry. This positions ANSTO as a capable and active contributor to NCT research globally and supports a growing pipeline of work with clinical and industry partners developing the next generation of NCT pharmaceuticals.

THE IMPACT

Filling this gap in national capability means Australian researchers and clinicians no longer depend solely on overseas access to develop novel NCT pharmaceuticals, optimise biological response or train the next generation of scientists and clinicians. As momentum behind neutron, proton and heavy ion therapies accelerates, this platform prepares Australia for the use and optimisation of these modalities when they arrive. The same simulation-plus-experimentation approach is transferable to other reactor and accelerator infrastructure not originally designed for biological research. The model extends beyond its application using Dingo. This strengthens ANSTO's standing as an international contributor to NCT research and provides a sovereign capability in Australia in preparation for new treatments as the technology becomes available.



Australian Research Priority or Futures Made in Australia Framework

- Supporting healthy and thriving communities

ANSTO strategic priority

- Deliver on Australia's priorities for the benefit of people, industry and the environment
- Improve the health of Australians by supporting access to current and future nuclear technologies
- Continue to be Australia's source of nuclear expertise, advice and services
- Lead the development of a nuclear-capable workforce

ANSTO capability/instrument

Australian Centre for Neutron Scattering
Dingo
Neutron Tomography
Neutron Activation Analysis
Radiation Biology

Collaborators/clients

- Dr Frederic Sierro
- Dr Joseph Bevitt
- Dr Ulf Garbe
- Dr Klaudius Jakubowski
- Attila Stopic
- Chris Dobie
- Sherryn Macleod
- Dr Mitra Safavi-Naeini

Paper DOI

doi.org/10.1038/s41598-025-02382-4

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Image:
T98G human glioblastoma cells following irradiation on the Dingo beamline, fixed and stained for filamentous actin (red) and nuclei (blue), with γH2AX immunofluorescence (green) marking sites of DNA double strand break repair. Inset: As direct visualisation of the NCT mechanism of action at the cellular level, a single nucleus shows an elongated γH2AX track, consistent with the ionisation path of an alpha particle or lithium-7 nucleus released by the 10B(n,α)7Li neutron capture reaction.

Evaluating new radiation source for next generation targeted therapy

THE CHALLENGE

Targeted cancer therapy using Auger electrons is appealing because it combines highly localised energy deposition with selective toxicity to target cells. Unlike alpha- and beta-emitting radionuclides, Auger emitters have low toxicity while circulating in blood or bone marrow but become highly cytotoxic when incorporated into cellular DNA. Their range is less than the diameter of a cell and significantly shorter than that of alpha and beta particles. The radioactivity is highly targeted to inflict DNA damage while minimising effects on surrounding healthy tissue. This makes Auger emitters promising for the treatment of micro-metastases. However, their wider clinical application is limited by incomplete understanding of the low energy they emit. Existing models do not accurately predict emissions, which reduces the precision of radiation dose calculations needed for treatment planning and evaluation.

THE SOLUTION

A solid-surface radiolabeling capability (below right) was established at ANSTO to produce ultra-thin, homogeneous radioactive sources for testing at The Australian National University (ANU) where teams would determine the nuclear decay of medically relevant radioisotopes.

Leveraging ANSTO's unique combination of facilities, licences, radioisotope supply and technical expertise, a radiolabelling methodology was developed and optimised. The research focused on two medically important radioisotopes: iodine-125 and molybdenum-99. The resulting data were used to benchmark the atomic-radiation database developed at ANU, which calculates accurate X-ray and electron energy distributions arising from atomic processes. The database will be made publicly available, and the validated data will subsequently be incorporated into the open-source GEANT4-DNA toolkit. This will make the information globally accessible to researchers and clinical medical physicists for improved patient dosimetry and health outcomes.

THE IMPACT

This collaboration has provided high-quality decay data for medically relevant radioisotopes and provided a stronger evidence base for evaluating radiation doses in current and next-generation targeted Auger electron therapies.

The research advances an understanding of the emission characteristics of these radioisotopes to inform the selection and application of radionuclides for different disease types, including tumours with varying biological and physical characteristics.

Translation of these findings into targeted radiotherapy has the potential to enhance treatment effectiveness through more accurate patient dosimetry, better-informed treatment planning and reduced radiation exposure to healthy tissue. By providing valuable experimental data to the medical physics community, this work contributes to the advancement of safer and more effective cancer treatments in Australia and globally.

Australian Research Priority or Futures Made in Australia Framework

- Supporting healthy and thriving communities

ANSTO strategic priority

- Improve the health of Australians by supporting access to current and future nuclear technologies
- Australia's source of nuclear expertise, advice and services

ANSTO capability/instrument

OPAL multi-purpose reactor
Molybdenum-99 Manufacturing Facility
Radioisotope research
Solid Surface Radiolabelling

Collaborators/clients

- Dr Bryan Pi Tee, formerly of Australian National University
- A/Prof Tibor Kibedi, Australian National University
- A/Prof Maarten Vos, Australian National University

ANSTO contributors

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- Dr Paul Pellegrini
- Dr Flora Mansour
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Paper DOI

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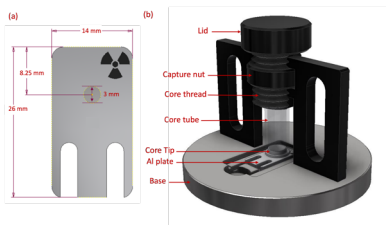

Image:
a) Deposition substrate (Aluminium plate) used for Mo-99 deposition. Note the yellow dashed-circular spot indicates the radiolabeling site (3 mm diameter). b) Design of the Deposition Jig used for Mo-99 radiolabeling on substrate.

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From atomic structures to drug discovery

THE CHALLENGE

Drug discovery increasingly depends on understanding not only static molecular structures but also an understanding of how proteins move, assemble and interact in living systems. Many high-value therapeutic targets, including viral regulatory proteins, cancer-related proteins, intrinsically disordered proteins and bacterial metabolic enzymes exist as dynamic molecular machines whose behaviour cannot be captured through conventional structural biology techniques alone.

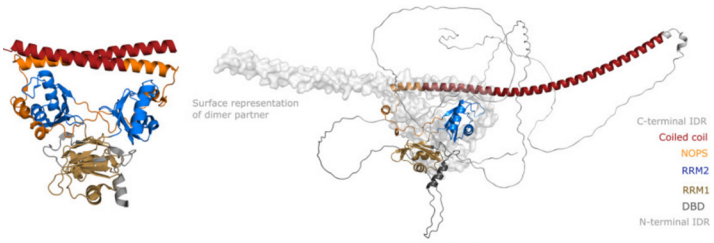
THE SOLUTION

Researchers at ANSTO and partner institutions combined capabilities spanning the Australian Synchrotron, Australian Centre for Neutron Scattering and National Deuteration Facility (NDF) to tackle these challenges. Scientists characterised the structures of proteins in solution associated with infectious disease and human health using Synchrotron techniques. Neutron scattering experiments, supported by deuterated proteins, provided unique contrast capabilities that revealed specific molecular components within complex assemblies. NMR spectroscopy, crystallography and mass spectrometry further complemented these studies to create a powerful multi-modal structural biology pipeline.

This integrated approach generated important insights applicable to multiple diseases. Studies of rabies virus phosphoproteins revealed how structure, RNA binding and other changes enable viral immune evasion and host-cell manipulation. Research on the human protein SFPQ elucidated the structural basis of interactions involving intrinsically disordered regions that drive formation of biomolecular structures implicated in neurodegenerative disease. Investigations of *Mycobacterium tuberculosis* exposed a previously unknown activation mechanism controlling bacterial metabolism during infection. The structural characterisation of an Estrogen receptor indicated that breast cancer-related mutations caused the protein to fold into a shape that could not be regulated and increased tumour cell growth. The results of these studies identified new opportunities for bacterial and cancer drug development.

THE IMPACT

These outcomes demonstrate how ANSTO's national infrastructure enables researchers to move beyond static structures to understand dynamic biological processes that underpin disease. The integration of neutron scattering, deuteration science, synchrotron and complementary structural biology methods is helping transform fundamental molecular discoveries into a knowledge base that supports future therapeutic innovation and improved global health outcomes.



Australian Research Priority or Futures Made in Australia Framework

- Supporting healthy, thriving communities

ANSTO strategic priority

- Use of national research infrastructure
- Deliver on Australia's priorities for the benefit of people, industry and the environment

ANSTO capability/instrument

Australian Synchrotron
BioSAXS
Biological small angle x-ray scattering
SAXS/WAXS
Small and Wide angle X-ray scattering

Australian Centre for Neutron Scattering
QUOKKA

National Deuteration Facility
Deuteration

Collaborators/clients

- A/Prof John Bruning, University of Adelaide
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- Prof Charlie Bond, University of Western Australia
- A/Prof Greg Moseley, Monash University

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- Dr Ashish Sethi

Paper DOI

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doi.org/10.1038/s42003-026-09821-6
doi.org/10.1107/S2059798325005303

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Image:
SFPQ protein

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Improving care for preterm babies

THE CHALLENGE

Advances in neonatal care mean more extremely pre-term babies are surviving than ever before with survival increasing from 43% in 1985 to 81% in 2021. However, up to 70% of these survivors develop a serious brain injury, intraventricular haemorrhage (IVH) with lifelong consequences. Nearly half of IVH cases occur within a critical window in the first six hours after birth.

Changing clinical resuscitation practice during this period requires strong, evidence-based validation to ensure that any intervention is both safe and effective for these highly vulnerable infants.

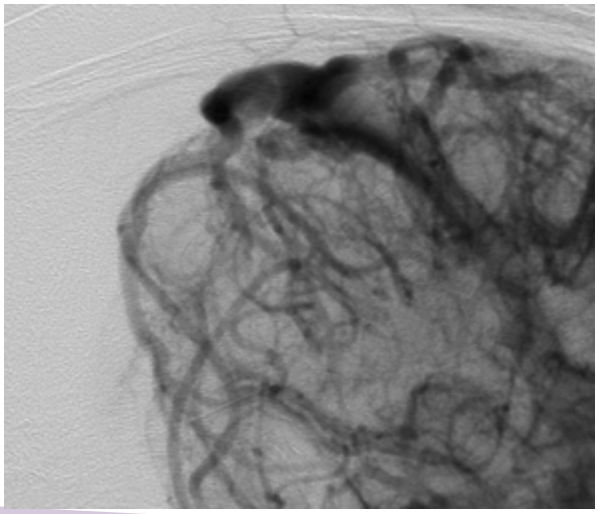
THE SOLUTION

A collaborative team led by Hudson Institute researchers has shown that establishing breathing before clamping the umbilical cord helps maintain stable blood flow to the brain preventing low oxygen levels (hypoxia) and reducing the risk of IVH. This approach, known as physiologically based cord clamping (PBCC), represents a simple but potentially transformative change to care at birth.

To translate PBCC into routine clinical practice, it must be rigorously validated and optimised. Advanced imaging at the Australian Synchrotron enables the direct measurement of cerebral blood flow and microvascular changes during this critical window. These capabilities provide unique, high-resolution insights into how PBCC function—insights that are not achievable with conventional clinical tools and supports a confident, evidence-based adoption in hospitals.

THE IMPACT

By leveraging Australia's world-leading imaging infrastructure to support clinically transformative research, this work has the potential to improve neonatal care practices worldwide. Widespread adoption of this technique could significantly reduce brain injury in extremely pre-term infants and improve survival and long-term developmental outcomes. This would reduce healthcare and disability costs and lessen the lifelong burden on individuals and families—helping give every baby, even those born too soon, the best possible start in life.



Australian Research Priority or Futures Made in Australia Framework

- Supporting healthy and thriving communities

ANSTO strategic priority

- Use of national research infrastructure
- Deliver on Australia's priorities for the benefit of people, industry and the environment

ANSTO capability/instrument

ANSTO Australian Synchrotron
IMBL
Imaging and Medical Beamline

Collaborators/clients

- Monash University
- The Hudson Institute of Medical Research
- National Cardiovascular Centre Japan
- RMIT University
- Monash Children's Hospital
- NHMRC

ANSTO contributors

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- Dr. Chris Hall
- Dr. Adam Round

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Image:
IMBL diagnostic imaging provides quantitative feedback enabling evidence-based comparison of resuscitation procedures to guide care for extremely pre-term babies.

Improving dairy foods with sustainable surfactants

THE CHALLENGE

Dairy emulsions are unstable systems containing oil and water domains separated by emulsifier layers. Saturated fats often crystallise at these oil-water interfaces and, when uncontrolled, this interfacial crystallisation breaks the emulsion, reducing shelf life. However, controlled fat crystallisation is essential to create structure in products like whipped cream and ice cream. Investigators hypothesised that different emulsifiers influence whether, and to what extent, interfacial crystallisation occurs. By selecting emulsifiers strategically, it is possible to control this process and regulate food structure and stability.

THE SOLUTION

Probing the microscopic interfaces between oil and water domains in emulsions is challenging. Using the small angle scattering instruments, researchers were able to use micrometre-sized X-ray beams to scan across confined oil-water interfaces in tiny steps. Each step across the interface revealed the molecular fingerprints of different fat crystal forms, which differ due to the arrangement of fat molecules inside the crystallites. They determined the amount and type of fat crystals. By introducing natural or synthetic emulsifiers, a stabilising layer formed at the interfaces and saw the modulation of fat crystallinity. The effects were highly dependent on emulsifiers with some promotion of crystallisation at the interface, some suppression of crystallisation and changes in the form of the fat crystals.

THE IMPACT

This work demonstrates that the selection of emulsifier directly controls interfacial lipid crystallisation in dairy emulsions. This allows the tailoring of product recipes using both naturally occurring surfactants and those synthesised from food industry by-products to either promote crystallisation for desired structure (as in whipped cream and ice cream) or suppress it to prevent emulsion breakdown and extend shelf life. This dual capability enables a precise control of product texture and stability and advances sustainable food formulation whilst maintaining acceptability to consumers.

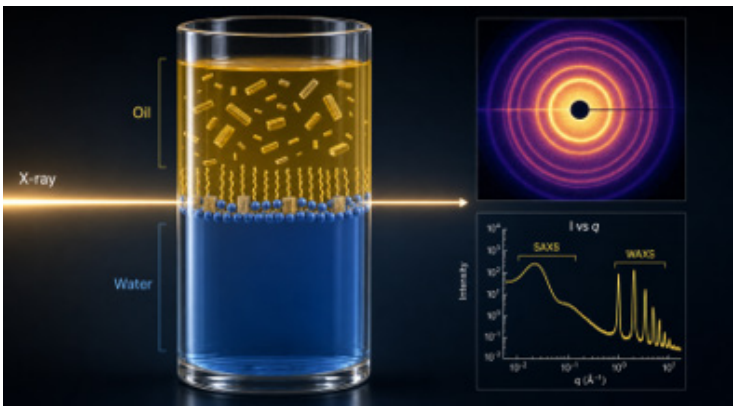

Image:
Scanning micro-sized X-ray beams across confined oil-water interfaces reveals the molecular fingerprints for fat crystal type and the influence of emulsifiers on their formation (Image generated by AI, Perplexity)

Australian Research Priority or Futures Made in Australia Framework

- Supporting healthy and thriving communities

ANSTO strategic priority

- Use of national research infrastructure
- Deliver on Australia's priorities for the benefit of people, industry and the environment

ANSTO capability/instrument

Australian Synchrotron
SAXS/WAXS
Small and Wide Angle X-ray Scattering

Collaborators/clients

- Professor Marta Krasowska, Adelaide University
- Dr Stephanie MacWilliams, Adelaide University
- Fonterra Research and Development Centre

ANSTO contributors

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Paper DOI

doi.org/10.1016/j.cis.2024.103138

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New approach to targeting antibiotic resistant bacteria

THE CHALLENGE

Polymyxin B is an antibiotic of last resort for treating infections; however, certain bacteria are starting to show signs of resistance even to this treatment. A new approach is needed to stop common infections from becoming deadly.

Lipidic nanoparticles are being used to deliver antibiotics to the surface of the bacterial cell, where they can be more effective in killing the bacteria. Lipid nanoparticles are fat molecules arranged in a particular shape and can be used to encapsulate antibiotics and other drugs.

In this work, a lipid with antibacterial properties called monolaurin was mixed with a nanocarrier lipid to make lipidic nanoparticles that look like tiny soccer balls known as a niosomes. The monolaurin-niosomes have been shown to be effective against certain multi-drug-resistant bacteria, especially when mixed with a treatment of polymyxin B.

The challenge for this work was to understand why the mixture of an existing antibiotic with a potential new treatment strategy was so effective.

THE SOLUTION

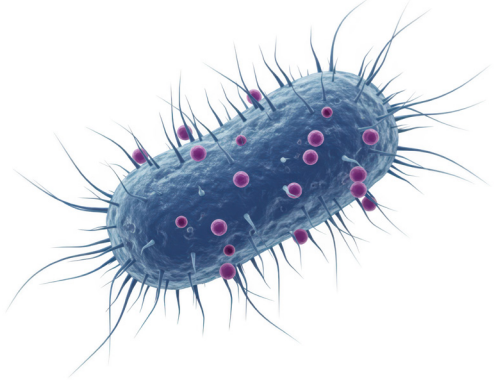
The cells of some bacteria are surrounded in a protective layer of long chains of sugars called polysaccharides. For this work, artificial membranes that mimic the properties of the bacterial cell surface, including the polysaccharides, were created for measurements using neutron reflectometry.

Neutron reflectometry is a valuable tool to understanding the structure of cell membranes at the nanometre length scale. In this research, measurements provided information about the mechanism at work in the monolaurin-niosome/polymyxin B treatment at the molecular level.

They showed that the monolaurin-niosomes target and remove the outer layer of the bacteria's membrane that is mainly composed of polysaccharides. This exposes the bacterial cell to polymyxin B to attack and breaks down the cell membrane, ultimately killing the bacterial cell.

THE IMPACT

This work shows that antibacterial lipids can be successfully used in combination with nanocarrier lipids to form anti-bacterial nanoparticles. This expands the possible delivery methods of established treatments, prolonging their effectiveness to treat bacterial infections and providing more time to search for new antibiotics.



Australian Research Priority or Futures Made in Australia Framework

- Supporting healthy and thriving communities

ANSTO strategic priority

- Use of national research infrastructure
- Deliver on Australia's priorities for the benefit of people, industry and the environment

ANSTO capability/instrument

Australian Centre for Neutron Scattering
Platypus
Neutron reflectometer
Spatz
Neutron reflectometer

Collaborators/clients

- A/Prof Hsin-Hui Shen
- Dr Xiangfeng Lai
- Prof Jian Li
- Prof Anton Peleg

ANSTO contributors

- Dr Anton Le Brun

Paper DOI

doi.org/10.1002/smll.202305052

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Image:
Nanoparticles binding to the surface of a bacterial cell. (Adobe stock)

New PET tracers for oxytocin research

THE CHALLENGE

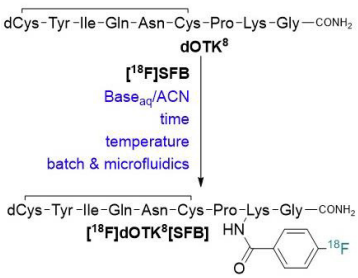
The oxytocin signalling system is vital for human social behaviours, including bonding, empathy and trust. Because of this, it is a primary therapeutic target for various clinical conditions. However, scientists have lacked precise molecular tools to see how oxytocin moves through the human body in real time. A major unanswered question remains whether oxytocin administered through the nose (the preferred non-hospital treatment route) effectively reaches the brain. Currently, because human studies rely on indirect measurement methods that lack scientific consensus, it is difficult to optimise therapies for social and emotional health conditions.

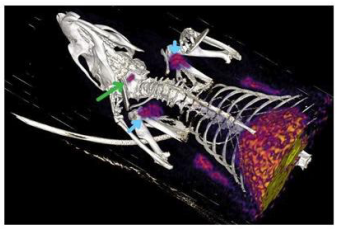
THE SOLUTION

In a major collaborative effort started in 2016, supported by an ARC grant, researchers from ANSTO and leading Australian universities designed and synthesised five novel oxytocin-like peptides suitable for Positron Emission Tomography (PET), an advanced medical imaging technique. The team identified a lead candidate which closely mimics natural oxytocin while remaining stable in the bloodstream. To produce this tracer, researchers used an innovative microfluidic technology, which allows for highly repeatable chemical reactions in tiny, controlled environments. Preclinical validation in animal models proved the tracer's effectiveness, as it successfully targeted oxytocin-rich tissues like the pituitary gland and mammary pads. Crucially, the team performed 'blocking' experiments to confirm that the tracer, known as [^{18}F]dOTK^{8}[SFB], was specifically engaging with the intended receptors. This milestone ensures the tracer is now ready for first-in-human trial studies of the biodistribution of oxytocin in the body.

THE IMPACT

This development provides the world's first successful oxytocin-like PET tracer suitable for human clinical studies. By enabling scientists to finally visualise how treatments reach their intended targets, this tool clears the path for personalized medicine tailored to social and emotional health. It will resolve the long-standing debate regarding which administration routes are most effective for delivering oxytocin to the brain. Ultimately, this research strengthens Australia's capability to develop innovative diagnostic treatments for better outcomes for patients with complex social and cognitive conditions.





Australian Research Priority or Futures Made in Australia Framework

- Supporting healthy and thriving communities

ANSTO strategic priority

- Deliver on Australia's priorities for the benefit of people, industry and the environment

ANSTO capability/instrument

Radiopharmaceutical development
Nuclear medicine imaging

Collaborators/clients

- Prof Adam Guastella, University of Sydney
- Dr Arvind Parmar, University of Sydney
- Dr Simone Zanoni, University of Sydney
- A/Prof Markus Muttenthaler, University of Queensland

ANSTO contributors

- Dr Giancarlo Pascali

Paper DOI

doi.org/10.1038/s42004-025-01649-1

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Image:
Scheme of the radiolabelling reaction and structure of the radiopharmaceutical (left), 3D rendering of the PET image highlighting the uptake in oxytocin-rich areas in rat (right).

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Revealing the hidden architecture of medical hydrogel

THE CHALLENGE

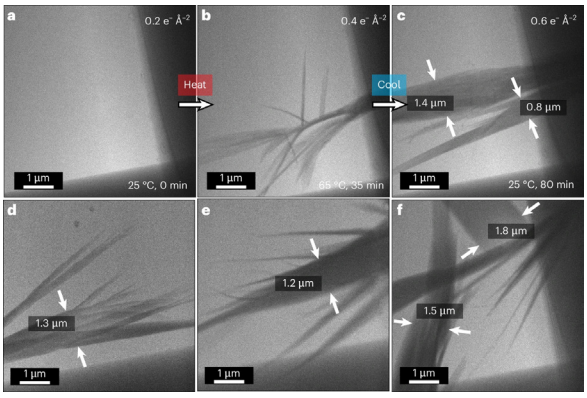
Methylcellulose is one of the most widely used hydrogel materials in biomedicine and consumer products, including drug delivery, contact lenses, wound healing, tissue engineering and food science. Yet its internal structure has remained difficult to observe in its natural, water-rich state without altering the gel. For decades, models assumed it formed a loose network of flexible nanoscale fibrils, but these models could not fully explain the gel's unexpectedly strong, reversible and mechanical behaviour. Researchers needed to find direct, minimally disruptive evidence of how methylcellulose assembles across nanometre-to-micrometre length scales.

THE SOLUTION

This landmark study by Northwestern University and international collaborators combined electron microscopy techniques and neutron scattering capabilities. It revealed methylcellulose hydrogel formation in a fully stabilised state in real time. The experiment avoided drying, freezing or shear artefacts that can disrupt soft networks. ANSTO's neutron scattering measurements then confirmed the same structures in bulk samples over length scales from 1 nanometre to 20 micrometres. The work revealed that methylcellulose does not remain a loose fibril network. Instead, individual fibrils assemble into tiered fibre-like bundles, 1 to 4 micrometres in diameter, that are up to 1,000 times more rigid than prior models predicted. These bundles, not the individual fibrils alone, largely determine gel strength and explain previously unresolved flow behaviour.

THE IMPACT

This discovery overturns the accepted structural model for a major hydrogel material and resolves a long-standing gap between predicted and observed mechanical behaviour. By showing that stiffness is governed by tiered bundles of fibrils, the study provides a stronger basis for rationally designing hydrogels with targeted properties and improved reliability. This has far-reaching implications for drug delivery, tissue engineering, wound healing, contact lenses, food science and other soft-material applications where performance depends on gel strength, stability and controlled response to temperature. The neutron scattering instruments were critical because they revealed nanometre- and micrometre-scale structures that standard characterisation methods had missed.



Australian Research Priority or Futures Made in Australia Framework

- Supporting healthy and thriving communities

ANSTO strategic priority

- Use of national research infrastructure
- Deliver on Australia's priorities for the benefit of people, industry and the environment

ANSTO capability/instrument

Australian Centre for Neutron Scattering
Kookaburra
Ultra-small angle scattering
Quokka
Small angle scattering

Collaborators/clients

- Northwestern University
- Case Western Reserve University
- University of Florida
- Argonne National Laboratory
- University of New South Wales

ANSTO contributors

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- Dr Kathleen Wood

Paper DOI

doi.org/10.1093/mam/ozaf048.937
doi.org/10.1038/s41563-026-02491-z

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Image:
Methylcellulose hydrogels form hierarchical fibre-like bundles rather than a loose network of flexible fibrils.

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Solving the hidden structure of the nutrient delivery system in milk

THE CHALLENGE

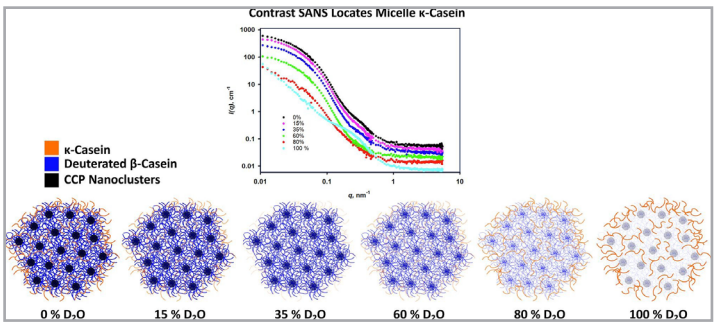
Milk contains tiny protein–mineral assemblies, miscelles, that deliver calcium, phosphate and protein while preventing harmful mineral deposits and the aggregation of proteins in the mammary gland. Despite decades of research, scientists have debated where an important protein, κ-casein, sat within these micelles and how it controlled stability. One model places κ-casein only on the surface as a protective coat; another predicts it is distributed throughout the structure. Resolving this question is important for understanding infant nutrition, dairy processing, mineral bioavailability, digestibility and the design of improved milk-based foods and ingredients.

THE SOLUTION

This study created simplified micelles that copied natural miscelles with controlled amounts of proteins of interest and nanoclusters of calcium phosphate. Researchers systematically varied concentrations and compared the resulting structures with predictions from models. Neutron scattering techniques with highly deuterated proteins could distinguish between different components in the micelles. Measurements showed how micelle size, substructure changed with different solvent conditions. The results were decisive. The κ-casein protein was not confined to an outer coat but distributed throughout the micelle, in agreement with newer binding models.

THE IMPACT

This work resolves a longstanding structural debate in dairy science and provides a more accurate foundation for understanding how milk stabilises calcium phosphate and key proteins. The findings improve knowledge of micelle stability, digestion, nutrient delivery and the self-assembly of mineral-proteins. These findings have relevance for infant formulas, cheese-making, yoghurt production and functional dairy ingredients. The study also demonstrates the value of neutron scattering and deuteration capabilities for answering biological and food-structure questions that cannot be resolved by conventional methods alone.



Australian Research Priority or Futures Made in Australia Framework

- Supporting healthy and thriving communities.

ANSTO strategic priority

- Use of national research infrastructure
- Deliver on Australia's priorities for the benefit of people, industry and the environment

ANSTO capability/instrument

Australian Centre for Neutron Scattering
Quokka
Small angle scattering

Australian Synchrotron
SAXS
Small angle scattering

National Deuteration Facility
Deuteration

Collaborators/clients

- CSIRO Agriculture and Food
- All G Foods
- Australian National University
- University of Glasgow

ANSTO contributors

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- Karyn L. Wild

Paper DOI

doi.org/10.1016/j.yjsbx.2024.100096

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Image:
Biomimetic casein micelles were assembled from β-casein, κ-casein and calcium phosphate nanoclusters to test competing models of milk structure. Using deuterated β-casein and contrast-variation SANS, the study showed that κ-casein is distributed throughout the micelle, supporting the multivalent-binding model rather than a surface-coat model.

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Supporting the development of next generation mRNA therapeutics

THE CHALLENGE

Lipid nanoparticles (LNPs) are the key lipid-based delivery system for mRNA therapeutics, utilised for delivery of the mRNA into the body, providing protection against degradation, allowing for cellular uptake and subsequent therapeutic function.

Ongoing challenges for development of new and improved LNP formulations for mRNA therapeutics efficacy and utilisation include reducing side-effects, enhancing targeted biodistribution, improving solubility and transport of therapeutics across membranes for increased bioavailability and transfection efficiency, increasing stability for cellular delivery improvements and cold-chain dependency for storage and supply-chain logistics for global distribution.

A lack of access to high-quality and high-purity deuterium-labelled (^2H) LNP components hinders the ability of academic researchers and industry to undertake tracing studies or investigate the structure and function of LNP drug delivery vehicles under a range of conditions using multiple characterisation techniques.

THE SOLUTION

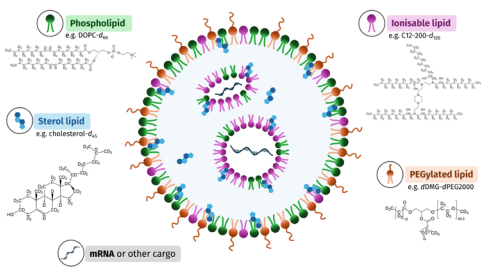
The National Deuteration Facility leveraged their expertise in applying chemical and biological techniques in deuteration of a range of compounds, to provide access to deuterium-labelled compounds across all types of molecules utilised in currently used LNP formulations for mRNA delivery and other lipid-based drug delivery systems.

Multiple custom-made deuterated lipids, many of which are not commercially available, have been supplied by the NDF to researchers and industry from each of the four typical LNP key components.

These lipids are particularly useful for application with neutron scattering experiments, where the substitution of deuterium for hydrogen provides contrast, which enables a higher quality and quantity of experimental data to be collected.

THE IMPACT

Understanding how LNPs work is essential for developing the next generation of mRNA therapeutics and ANSTO is playing a direct role in making this possible. Studies have revealed how cholesterol shapes LNP structure, how some lipids influence mRNA release and other insights to help researchers to design safer, more effective mRNA vaccines and therapies that could benefit millions.



Australian Research Priority or Futures Made in Australia Framework

- Supporting healthy and thriving communities

ANSTO strategic priority

- Use of national research infrastructure
- Deliver on Australia's priorities for the benefit of people, industry and the environment

ANSTO capability/instrument

National Deuteration Facility
Deuteration

Collaborators/clients

- Academic researchers (multiple)
- Industry (Moderna, Sanofi, CureVac)
- NSW RNA Institute
- Jülich Centre for Neutron Science (JCNS) Deuteration Service

ANSTO contributors

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Synchrotron techniques will help untreatable cancers

THE CHALLENGE

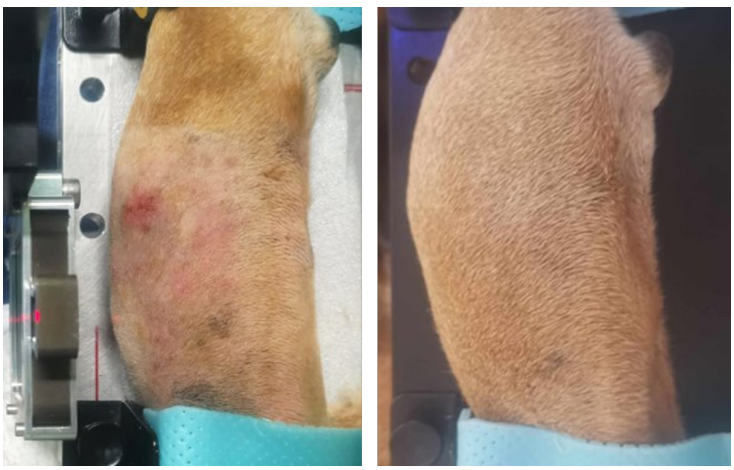
Despite advances in surgery, chemotherapy, and radiotherapy, survival rates for some cancers have remained unchanged for decades. For example, survival for head and neck cancers are still at 30% despite 35 years of developments. A therapy that could safely treat tumours while minimising damage to surrounding healthy tissue—particularly in sensitive regions such as the brain and spinal cord—would be a breakthrough. It would offer improved outcomes and renewed hope for patients and families where current treatments offer limited chances of survival.

THE SOLUTION

Microbeam Radiation Therapy (MRT) belongs to a new class of treatments, which are an advanced radio-oncology technique that deliver high-dose radiation peaks separated by low-dose 'valleys'. Spatially Fractionated Radiation Therapy (SFRT) treats tumours in a way that is not uniform. It achieves dramatic symptom relief and tumour shrinkage in bulky cancers or those resistant to radiotherapy while rigorously protecting surrounding healthy tissues and critical organs. MRT divides the radiation beam in such a way that healthy tissue can recover rapidly while tumour tissue is destroyed. MRT has also proven therapeutic advantages, such as triggering an anti-tumour immune response and increasing a tumour's ability to take in fluids, proteins and cells. These effects open opportunities for more effective combination treatments with immunotherapy and chemotherapy. As a capability unique to synchrotron sources and currently solely available at the Australian Synchrotron, MRT is a fundamentally new way to treat cancers that are difficult or unsafe to treat with existing technologies.

THE IMPACT

Veterinary clinical studies in canine patients with naturally occurring tumours have shown promising outcomes, including rapid tumour shrinkage following a single MRT treatment. This suggests the feasibility of applying to human patients with an improved outcome. As the research progresses toward human clinical trials, MRT has the potential to improve cancer care and survival for difficult-to-treat cancers. It enables a more effective combination therapies to deliver improved treatments offering fresh hope for patients with currently untreatable cancers.



Australian Research Priority or Futures Made in Australia Framework

- Supporting healthy and thriving communities

ANSTO strategic priority

- Deliver on Australia's priorities for the benefit of people, industry and the environment

ANSTO capability/instrument

Australian Synchrotron

IMBL

Imaging and medical beamline

Collaborators/clients

- University of Bern
- University of Wollongong
- Peter Macallum Cancer Centre
- University of Rostock
- NHMRC

ANSTO contributors

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- Dr. Adam Round
- Other contributors
- Dr. Matthew Cameron

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Image:
Canine osteosarcoma (bone cancer) treated with MRT. (Left): Diseased area before treatment. (Right): Same area two months after a single MRT treatment, showing shrinkage of the tumour.

Synthetic materials that mimic living soft tissues

THE CHALLENGE

Tissue engineering and regenerative medicine need safe, reproducible materials that mimic the structure of the soft scaffold that supports cells, guides tissue development and responds to mechanical forces. Natural matrices such as Matrigel® can support cell growth, but they vary between batches, may trigger immune concerns and are difficult to tailor for specific applications. Fully synthetic hydrogels offer greater control, yet often fail to combine tissue-like mechanics, biological activity, antimicrobial function and practical handling. Researchers needed a synthetic material that could support living cells while remaining tunable, injectable, scalable and easy to use.

THE SOLUTION

This UNSW-led study, with ANSTO involvement, discovered a new family of self-assembling hydrogels based on a type of short peptide. Molecular design identified variations that spontaneously fold and assemble into fibrous, tiered networks spanning nanometres to micrometres, without complex manufacturing steps. Neutron scattering instruments helped reveal the multiscale structure of the gels, including nanometre-scale structures that evolve over time. The resulting trpzip hydrogels are self-healing, shear-thin, injectable and stress-relaxing, with many other advantageous properties.

THE IMPACT

This research provides a fully synthetic, reproducible platform for growing, harvesting and delivering living cells. By combining tissue-like mechanical properties, antimicrobial activity, bioactivity and practical handling in one material, trpzip hydrogels address several limitations of current natural and synthetic materials. They could support the computational modelling of disease, drug testing, cell therapy and three-dimensional bioprinting and can be delivered less invasively. The work demonstrates how ANSTO neutron scattering can reveal the internal architecture of complex biomaterials and help connect molecular design, nanoscale structure and real biomedical function.

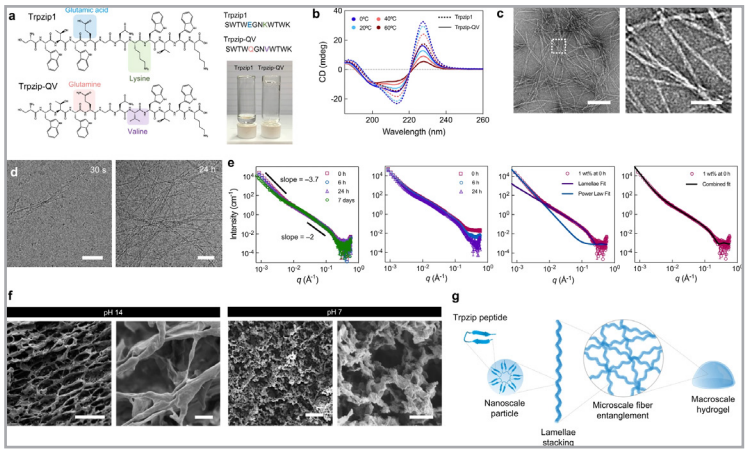

Image :
Synthesis and characterisation of trpzip hydrogels. (a) trpzip peptide design and gel formation. (b) Circular dichroism confirms peptide folding. (c) TEM shows trpzip-QV nanofibres. (d) Cryo-TEM captures hydrogel assembly over time. (e) Small angle neutron scattering reveals hierarchical nanoscale and microscale structure. (f) SEM shows hydrogel network morphology at different pH. (g) Proposed self-assembly pathway from peptide monomers to hydrogel.

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Australian Research Priority or Futures Made in Australia Framework

- Supporting healthy and thriving communities.

ANSTO strategic priority

- Use of national research infrastructure
- Deliver on Australia's priorities for the benefit of people, industry and the environment

ANSTO capability/instrument

Australian Centre for Neutron Scattering
Kookaburra
Ultra-small angle scattering
Quokka
Small angle scattering

Collaborators/clients

- University of New South Wales
- Australian Centre for Nanomedicine
- Sydney Children's Hospital Network
- Molecular and Integrative Cystic Fibrosis Research Centre;

Publications

doi.org/10.1038/s41467-023-41907-1

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Testing radiation damage in cells for space travel

THE CHALLENGE

Astronauts on long missions to the Moon or Mars face cosmic radiation, a hazard that is hard to predict. Beyond the protection of low Earth orbit, high-energy particles strike the body in ways ground-based studies struggle to reproduce, and current safety limits rest on uncertain estimates of how human cells respond. Recent evidence suggests those limits may understate the true risk, especially during solar storms. Computer tools can simulate how radiation damages cells, but a simulation is only as trustworthy as the real measurements used to check it, and that high-quality biological data has been missing.

THE SOLUTION

Researchers from the University of Wollongong, Swinburne University of Technology and ANSTO produced the missing data under tightly controlled conditions, then used it to test the model. Ion irradiation at the Centre for Accelerator Science was used to deliver protons, carbon ions and oxygen ions, three components of cosmic radiation, to layers of human skin cells at specific doses. An ion crossing a cell can break both strands of its DNA. The team stained a protein in the cell that gathers at each break and counted the bright spots by eye to estimate the damage. In parallel, they built a detailed simulation of the same damage. Comparing the two measurements reveals whether the model reproduces what actually occurs in a cell. Together, the measurements and the simulation form a benchmark that other researchers can use to check and improve their own radiation models for space health and for radiation therapies on Earth.

THE IMPACT

The work gives radiation-damage models something they have lacked: careful real-cell measurements to be tested against. A model that reproduces these results can be trusted to predict how cosmic radiation harms tissue in places no experiment can reach, supporting a fresh look at astronaut safety limits and the shielding and countermeasures that deep-space missions will need. The benchmark datasets are shared internationally, and the same validated tools sharpen radiation therapies that depend on accurate models of how ions damage cells. This places ANSTO among the few laboratories that can measure radiation biology at this level of detail.

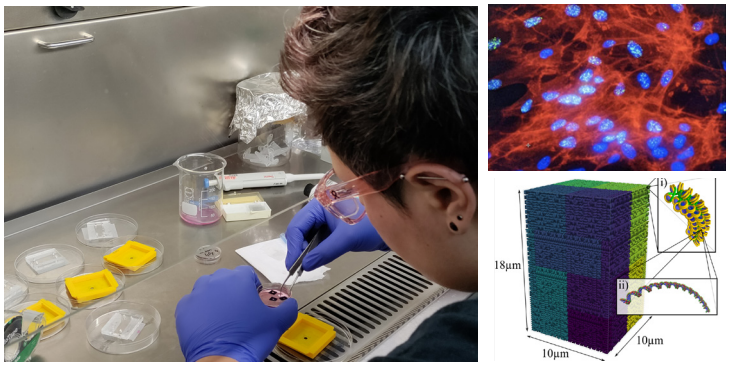

Image:
(A) Preparing samples at ANSTO's cellular biology laboratory, where human cells are grown on an ultra-thin silicon nitride membrane for irradiation. (B) DNA breaks in an ion-struck cell nucleus, marked with fluorescent dye. (C) The matching Geant4-DNA simulation of the same damage, used to benchmark the model.

Australian Research Priority or Futures Made in Australia Framework

- Supporting healthy and thriving communities

ANSTO strategic priority

- Deliver on Australia's priorities for the benefit of people, industry and the environment

ANSTO capability/instrument

Centre for Accelerator Science
Heavy Ion Nuclear Microprobe
Cellular and Molecular Laboratories

Collaborators/clients

- Prof Susanna Guatelli, University of Wollongong
- Prof Moeava Tehei & Team, University of Wollongong
- Prof Jeremy Brown, Swinburne University of Technology

ANSTO contributors

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- Dr Ryan Drury
- Dr Melanie Ferlazzo
- Dr Zeljko Pastuovic
- Mr Nicholas Howell

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Testing simulations that design compact neutron sources

THE CHALLENGE

Neutron beams treat cancer, probe materials, produce medical isotopes and underpin nuclear security, but every application depends on a source of neutrons. Research reactors such as ANSTO's Open Pool Lightwater Reactor (OPAL) are world class, but there are few like it in the world. Compact accelerator-based sources can bring neutrons into hospitals and factories, and their adoption is accelerating worldwide. Everything downstream of such a technology, its neutron yield, energy spectrum, shielding and activation, is set by one component: the target that converts the ion beam into neutrons. Designers choose it by simulation, yet no one has previously rigorously tested whether the leading predictive data agree with experiment or each other.

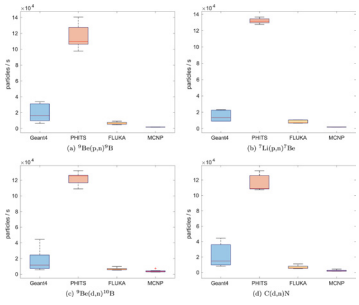
THE SOLUTION

The team ran the four major simulation codes, Geant4, PHITS, FLUKA and MCNP, through an identical battery of tests. These assessments included the four nuclear reactions most likely to power compact sources using lithium, beryllium and carbon targets; simulated across all parameters that matter for design. Every prediction was compared against decades of published experimental measurements. The verdict is practical. Geant4, MCNP and PHITS predict total neutron yield best. Where experimental benchmarks exist, the codes agree with each other to within about 10% to 30%. PHITS reproduces measured energy spectra most faithfully and runs more than six times faster than the others. The simulations confirmed that no single code is superior. The study also mapped the gaps, the energies and angles where no experimental data had existed and simulation remained unverified.

THE IMPACT

Someone designing a compact neutron source can now pick the right tool with evidence instead of habit or convenience and know exactly where its predictions can be trusted. That predictability lowers the cost and risk of building the sources to bring neutron capture therapy into hospitals and cancer centres that will never have a reactor. The gap map doubles as an experimental to-do list of the next measurements. The work was undertaken with partners in Australia, the United States and Japan.

A



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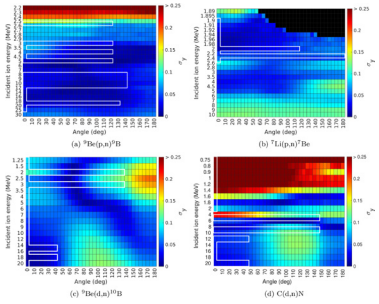

Australian Research Priority or Futures Made in Australia Framework

- Supporting healthy and thriving communities
- Building a secure and resilient nation

ANSTO strategic priority

- Deliver on Australia's priorities for the benefit of people, industry and the environment

ANSTO capability/instrument

Radiation transport modelling

Collaborators/clients

- University of Wollongong
- University of Technology Sydney
- Brookhaven National Laboratory, USA
- QST, Japan

ANSTO contributors

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- Dr Mitra Safavi-Naeini

Paper DOI

doi.org/10.1016/j.cpc.2025.109998.

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Image:
(A) Where the four codes agree and where data is missing; outlined regions have experimental benchmarks. (B) PHITS runs the same simulations in under one sixth the time of the other codes.

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Understanding the architecture of red blood cells

THE CHALLENGE

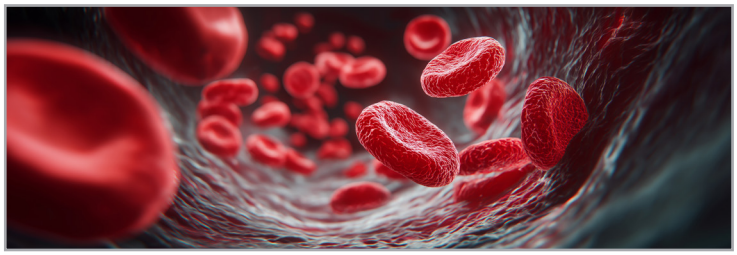
Biomaterials derived from red blood cells are increasingly being used as the basis for drug delivery vehicles. Materials from these are naturally well-tolerated by the body and can circulate in the bloodstream for extended periods without triggering an immune response. Despite the promise red blood cell biomaterials in fields such as cancer therapy, blood substitutes and cardiovascular disease, a deeper understanding of their structural features and biological behaviour is still needed to advance clinical use. Standard imaging and characterisation methods often fall short in capturing the details needed in these systems. Insights at the nano- to micro-scale are essential to unravel the complex interactions and structural dynamics of these materials.

THE SOLUTION

Two types of human red blood cells were chosen for study, 'Red Blood Cell ghosts', which are essentially empty shells made by carefully removing the cell's contents; and 'Red Blood Cell-derived extracellular vesicles', which are bubble-like particles naturally shed by red blood cells. To address the challenges in studying the structure of these two materials, the team used neutron scattering techniques. These non-destructive techniques are uniquely suited for probing these materials at nano- to micro-scale. They provide detailed insight into particle size, shape, internal layering and molecular interaction; all while preserving sample integrity within relevant environmental conditions.

THE IMPACT

This work revealed that the Red Blood Cell extracellular vesicles are spherical particles about 260 nanometres across with a 3-nanometre membrane, and that roughly 87% of their interior is water with around 10% of the internal contents likely made up of proteins. Notably, the membrane structure of these was found to differ from that of the Red Blood Cell ghosts, offering new clues about how these particles form. Findings from this study have given a detailed structural blueprint that could help rationally engineer red blood cell-derived materials for more effective drug delivery, diagnostics and other medical applications.



Australian Research Priority or Futures Made in Australia Framework

- Supporting healthy and thriving communities

ANSTO strategic priority

- Use of national research infrastructure
- Deliver on Australia's priorities for the benefit of people, industry and the environment

ANSTO capability/instrument

Australian Centre for Neutron Scattering
Bilby
Small angle scattering
Kookaburra
Ultra-small angle scattering

Collaborators/clients

- Baker Heart and Diabetes Institute
- University of Melbourne
- La Trobe University
- Monash University

ANSTO contributors

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- Dr Liliana de Campo

Paper DOI

doi.org/10.1002/sstr.202500369

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Image: Red Blood Cells (Adobe Stock)



Environment

Nuclear science and technology are powerful tools to protect the environment

Nuclear science is a powerful tool in protecting our environment.

Stable and radioactive forms of the elements found in nature can be used to trace the pathways and impacts of contaminants in people, biota and the environment.

ANSTO nuclear science and technology helps Australians understand, protect and restore precious natural environments, while supporting more sustainable use of resources.

Our environmental research focuses on improving the sustainable management and quality of water resources, food and agriculture in Australia.

Experience in environmental monitoring and remediation expertise, and the development of approaches that contribute to emissions reduction and environmental stewardship, are also crucial to address climate change. This is underpinned by our research providing an understanding of how past natural and human events have impacted the environment.

A 3D view of NSW groundwater informs management

THE CHALLENGE

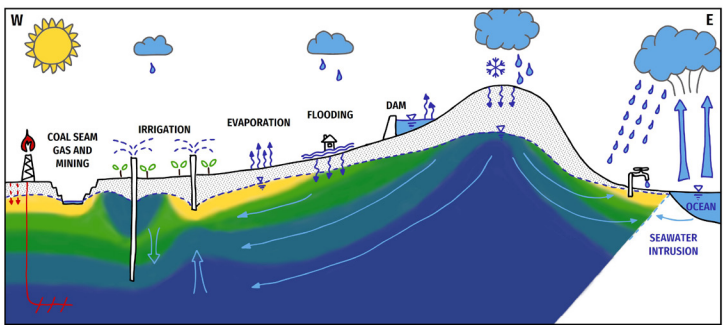
Groundwater is a critical water resource in New South Wales (NSW), yet its sources, recharge mechanisms and flow processes remain poorly understood at a regional scale. Traditional hydrogeological approaches, such as water level monitoring and water balance methods, fail to capture system complexity, including depth-dependent processes, aquifer mixing and human influences. Without a state-wide groundwater framework, it has been difficult to distinguish recharge sources such as rainfall, flooding or snowmelt. This limitation impacts groundwater management amid rising demand and climatic variability. The key challenge was, therefore, to develop a state-wide framework using stable water isotopes to characterise groundwater origin, recharge mechanisms and flow processes across the landscape and depth.

THE SOLUTION

Stable water isotopes provide a robust tracer of water origin and transformation, enabling insight into recharge pathways and processes across complex aquifer systems. This study developed the first multi-depth, state-wide groundwater isoscape (isotope map) for NSW by integrating more than 4000 measurements from new and existing datasets. Using geostatistical methods, isotopes were mapped across four depth intervals from shallow (1–30 m) to deep (300–1000 m), creating a three-dimensional representation of groundwater behaviour. The results revealed clear patterns, including increasing evaporation inland, evidence of flood and snowmelt recharge and distinct differences between shallow, modern groundwater and deeper, older waters. These findings show that groundwater recharge in NSW is controlled by multiple interacting natural and anthropogenic processes, varying significantly across space and depth.

THE IMPACT

This work provides the first comprehensive baseline for groundwater using isotopes in NSW, providing a powerful tool for both research and water management. The isoscapes enable clearer identification of recharge sources and processes, detection of human impacts (such as irrigation and land-use change), and improved prediction in data-poor areas. The framework supports informed groundwater allocation, sustainability assessments and protection of groundwater-dependent ecosystems. Scientifically, it demonstrates how isotopes can distinguish modern from historical recharge and reveal complex aquifer interactions. Overall, it strengthens the capacity to manage groundwater resources under growing demand and climatic uncertainty using approaches transferable to other regions.



Australian Research Priority or Futures Made in Australia Framework

- Protecting and restoring Australia's environment

ANSTO strategic priority

- Deliver on Australia's priorities for the benefit of people, industry and the environment

ANSTO capability/instrument

Environment stable isotope laboratory – IRMS - ($\delta^{18}O$, $\delta^{2}H$)

Collaborators/clients

- NSW Department of Climate Change, Energy, the Environment and Water
- National Water Grid

ANSTO contributors

- Dr Dioni I. Cendón
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- Dr Jagoda Crawford
- Dr Liza K. McDonough
- Dr Catherine E. Hughes
- Dr Karina T. Meredith

Paper DOI

doi.org/10.1016/j.ejrh.2025.102732

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Image:
Conceptual cross-section across NSW showing processes locally affecting groundwater.

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A solution to retain climate information in water during biosecurity treatment

THE CHALLENGE

Environmental samples imported to Australia can reveal how carbon moves through ecosystems and how environments respond to climate change. To safely transport these samples into Australia, strict biosecurity rules require them to be sterilised, often using gamma irradiation, a process that eliminates microorganisms. This treatment, however, can unintentionally alter the chemical signals that scientists analyse. Dissolved organic matter, the complex mix of carbon compounds found in water, acts as a natural archive of environmental processes. If the energy of irradiation during sterilisation breaks apart these molecules, researchers risk mistaking treatment effects for real changes in the ecosystem.

THE SOLUTION

Researchers investigated whether freezing water samples before gamma irradiation and having them remain frozen during treatment at the Gamma Technology Research Irradiator facilities at ANSTO could prevent unwanted changes to the chemical composition of organic matter in water samples. River water samples were collected and divided into three treatments: untreated samples, irradiated samples kept unfrozen, and irradiated samples frozen solid. Samples were then analysed for dissolved organic carbon concentration, composition and isotopes. Samples irradiated unfrozen showed major changes, including loss of carbon, altered composition and shifts in isotopic data. Notably, these changes were not evident in samples irradiated frozen, where parameters remained largely unchanged. Researchers identified that freezing samples physically limits the movement of highly reactive molecules produced during irradiation, preventing them from breaking down dissolved organic matter, effectively preserving the chemical integrity of carbon in the samples.

THE IMPACT

The findings show that gamma irradiation, a treatment designed to safeguard the environment, can unintentionally compromise environmental data. These results carry important implications for the handling of data produced from irradiated environmental samples, whereby large differences in dissolved organic matter parameters may be inadvertently attributed to ecological or carbon cycling processes. Irradiating samples in a frozen state provides a practical and effective strategy to preserve carbon quantity, structure and isotopic integrity. By protecting the integrity of water samples, this method helps ensure that critical climate information from Antarctica and other remote environments remains reliable.



Australian Research Priority or Futures Made in Australia Framework

- Protecting and restoring Australia's environment

ANSTO strategic priority

- Deliver on Australia's priorities for the benefit of people, industry and the environment

ANSTO capability/instrument

IC
ICP-AES
IRMS (^{13}C, ^{18}O, ^{2}H)
GATRI (γ irradiation)

Collaborators/clients

- Securing Antarctica's Environmental Future (SR200100005)
- Australian Antarctic Division (AAD) Field support AAS 4628

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Image:
Changes due to treatment observed not only in sample parameters but also sample bottles. Control (left) remains unchanged, while irradiated unfrozen (middle) shows most distinct lid colour change.

Achieving sustainable mining with biological innovation

THE CHALLENGE

The global transition to renewable energy technologies is driving increased demand for rare earth elements used in products such as LEDs, solar panels, and other clean-energy systems. Traditional mining methods for these critical materials are often energy-intensive, environmentally disruptive, and cannot target elements selectively. At the same time, mining operations generate substantial volumes of tailings that can contribute to heavy metal contamination, acid mine drainage, dust generation, and long-term environmental liabilities. Together, these challenges highlight the need for innovative and sustainable approaches to resource recovery and mine waste management.

THE SOLUTION

Researchers investigated two complementary biological approaches to improve the sustainability of mining and resource management.

The first approach used microalgae to selectively capture rare earth elements using phosphate-rich granules. The Australian Synchrotron's Medium Energy X-ray Absorption Spectroscopy beamlines (MEX2 and MEX1) were used to understand how these granules form within microalgae and how they interact with rare earth elements, such as gadolinium and cerium. The research demonstrated that microalgae convert environmental phosphorus into acid granules that can also bind rare earth elements.

The second approach focused on the remediation of mine tailings. Kimberlite tailings were treated with metal-metabolising bacteria in bioreactors to promote the formation of secondary minerals, including carbonates. X-ray Fluorescence Microscopy (XFM) was used to investigate the formation of minerals and the distribution of metals. Over several months, treated systems produced approximately twice as much carbonate as untreated samples while increasing atmospheric carbon capture and stabilise tailings to reduce environmental risks.

THE IMPACT

The research demonstrates how biological systems can transform mining and waste-management practices.

Microalgae were shown to selectively interact with rare earth elements through their phosphorus granules, which provided new insights into environmentally sustainable rare earth extraction and separation. Beyond mining applications, the algae's ability to capture and store phosphorus offers opportunities in wastewater treatment and the recovery of nutrients for agricultural use.

Similarly, microbial treatment of mine tailings offers a pathway to convert mining waste into a valuable environmental resource. Enhanced carbonate formation enables long-term carbon capture, while microbial processes help reduce heavy metal movement, minimise acid mine drainage and support vegetation growth that stabilises tailings deposits.

These studies demonstrated how advanced synchrotron techniques can support the development of sustainable mining technologies to recover critical resources, reduce environmental impacts and contribute to global decarbonisation efforts.

Australian Research Priority or Futures Made in Australia Framework

- Transitioning to a net zero future

ANSTO strategic priority

- Deliver on Australia's priorities for the benefit of people, industry and the environment

ANSTO capability/instrument

Australian Synchrotron
XFM
X-ray Fluorescence Microprobe Australian Synchrotron
MEX1 & MEX2
Medium Energy X-ray Absorption Spectroscopy

Collaborators/clients

- University of Queensland
- Vietti Slurrytec
- Prof. Richard Haverkamp - Massey University, New Zealand

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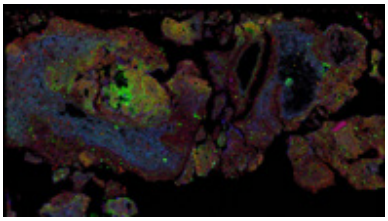

Image:
Tailings from Princess Creek , Tasmania.

Antarctica's hidden lake chemistry reveals changes to climate

THE CHALLENGE

Antarctica's lakes may appear frozen and untouched, but they are highly sensitive ecosystems already responding to climate change. The problem is that the earliest signs of environmental disruption often occur at the molecular level long before visible changes appear in the landscape. Scientists needed to determine whether the chemistry of Antarctic lake water could reveal these hidden ecosystem shifts and provide an early warning system for how a warming climate is reshaping one of Earth's most vulnerable regions.

THE SOLUTION

Researchers from ANSTO, the University of Wollongong, Florida State University and the National High Magnetic Field Laboratory in Tallahassee analysed lake waters near Casey Station in East Antarctica using ultra-high-resolution mass spectrometry capable of detecting thousands of individual organic molecules within a single drop of water. By combining molecular chemistry and isotope analysis, the team uncovered distinct chemical fingerprints linked to penguin colonies, moss beds, microbial activity and glacial meltwater.

The study showed that even subtle environmental shifts leave measurable molecular traces in lake water. Penguin-influenced lakes contained nitrogen-rich organic compounds derived from guano, while moss-dominated systems carried distinct plant-based signatures. The research also suggests that Antarctic microbes may currently help conserve carbon within these nutrient-limited lakes. However, as warming accelerates ice melt, more organic carbon is released into the environment, which could cause these microbial processes to shift and change how Antarctic lakes store and cycle carbon in the future.

THE IMPACT

This research transforms our understanding of Antarctic lakes as remote water bodies into powerful indicators of environmental change. The findings establish the first molecular-scale organic matter baselines for lake ecosystems located within Australian Antarctic territory. It provides scientists with a new way to detect climate-driven change before it becomes visible across the landscape. The work also highlights a potentially emerging climate risk. As Antarctica warms, changes in microbial carbon cycling could alter whether these lakes continue storing carbon or begin releasing more of it into the atmosphere. Beyond Antarctica, the study advances global understanding of how fragile polar ecosystems respond to accelerating climate change.



Image:
Field team collecting samples in Antarctic lakes (photo credit: Barry Becker).

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Australian Research Priority or Futures Made in Australia Framework

- Protecting and restoring Australia's environment

ANSTO strategic priority

- Deliver on Australia's priorities for the benefit of people, industry and the environment

ANSTO capability/instrument

IC
ICP-AES
IRMS (^{13}C, ^{18}O, ^{2}H)
GATRI (γ irradiation)

Collaborators/clients

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- Dist Prof Sharon Robinson, University of Wollongong
- Eliza Hamilton, University of Wollongong
- Amy Holt, Florida State University
- Prof Robert Spencer, Florida State University, USA
- Dr Amy McKenna, National High Magnetic Field Laboratory
- Securing Antarctica's Environmental Future (SR200100005). Field support provided by the AAD through AAS 4628.

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Authentication of Kakadu plum origin strengthens traceability in Australia's native bushfood industry

THE CHALLENGE

For more than 60,000 years, Aboriginal communities have harvested Kakadu plum *Terminalia ferdinandiana* as a traditional food and medicine. Today, its exceptional vitamin C and antioxidant content has driven rapidly growing global demand, creating new economic opportunities for Indigenous communities. However, commercialisation has also increased the risk of food fraud, product mislabelling, cultural exploitation and unsustainable harvesting practices. Without an independent way to verify the source of the fruit, the industry lacked a robust mechanism to protect Indigenous-led supply chains, authenticate provenance claims, and ensure that economic benefits flow back to Traditional Owners, Custodians and harvesters.

THE SOLUTION

ANSTO partnered with the Northern Australia Aboriginal Kakadu Plum Alliance (NAAKPA) to develop a scientific provenance authentication system based on elemental and stable isotope fingerprinting. Using X-ray fluorescence (XRF) and spectrometry, researchers characterised the unique chemical signatures of Kakadu plum sourced from different regions across northern Australia. These data were used to establish a reference database and predictive models capable of linking fruit and products to their geographic origin. The research demonstrated that Kakadu plum carries distinct regional fingerprints that can be used to verify provenance, detect fraudulent products and strengthen traceability throughout the supply chain. The project also evaluated portable XRF technology, providing a pathway for rapid, field-based provenance screening.

THE IMPACT

This research established a provenance authentication framework for Kakadu plum, demonstrating that elemental and stable isotope fingerprints can be used to verify geographic origin and strengthen traceability throughout the supply chain. The work provides the scientific foundation for provenance certification and future geographic indication (GI) schemes within Australia's native bushfood industry. By enabling independent verification of origin, the technology helps deter fraud, improve consumer confidence and support sustainable industry growth. Most importantly, it helps ensure that the cultural and economic value of Kakadu plum remains connected to the Indigenous communities that have managed and harvested this resource for millennia, creating new opportunities for Indigenous-led enterprise and market participation.



Australian Research Priority or Futures Made in Australia Framework

- Elevating Aboriginal and Torres Strait Islander knowledge systems

ANSTO strategic priority

- Deliver on Australia's priorities for the benefit of people, industry and the environment

ANSTO capability/instrument

Stable Isotope Analysis (EA-IRMS)
X-ray fluorescence (XRF) analysis using ITRAX and portable scanner

Collaborators/clients

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Image:
ANSTO's elemental and stable isotope fingerprinting verifies Kakadu plum provenance, helping protect Indigenous cultural heritage, prevent food fraud and build confidence in Australia's native bushfood industry. Photo provided by NAAKPA.

Breaking down plastics with an enzyme

THE CHALLENGE

Our world creates 350 million tons of plastic waste each year that results in a buildup of pollution and microplastics. These microplastics attract harmful chemicals that end up in our food, and impact the health of humans, animals and the broader environment. About 10% of plastic waste is made of polyethylene terephthalate (PET). PET is valued for its chemical stability and durability, but these same qualities make it challenging to break down. A safe and sustainable world requires better solutions for the recovery and recycling of PET plastics.

THE SOLUTION

In 2016, a plastic digesting bacterium, *I.sakaiensis*, was first discovered in a recycling plant. It creates an enzyme, PETase, capable of breaking down PET into recyclable plastic. But to be integrated into industrial recycling processes, PETase must be able to withstand high temperatures.

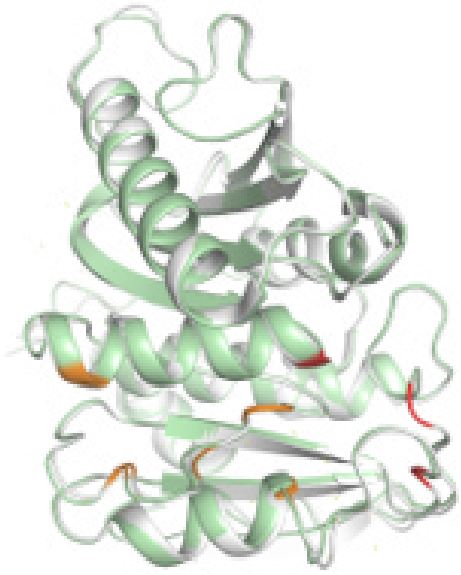
Australian researchers from CSIRO and the Australian National University looked at the evolution of this enzyme by analysing genes and proteins. They reconstructed ancestral enzymes, studied their properties and revealed a trade-off between PET breakdown and heat resistance.

Samples of these enzymes were analysed on the Macromolecular crystallography (MX2) beamline to produce 3D models of ancestral PETase that explained the trade-off between the breakdown activity of PETase and overall heat resistance.

THE IMPACT

The design of PETase enzymes can provide a low-energy and environmentally friendly alternative to current disposal methods, such as landfills and incineration. The findings will help advance recyling with enzymatic PET, which can help with pressing environmental and economic challenges associated with plastic waste.

This content was adapted from a case study prepared by Dr Chris Szeto.



Australian Research Priority or Futures Made in Australia Framework

- Protecting and restoring Australia's enviroment

ANSTO strategic priority

- Deliver on Australia's priorities for the benefit of people, industry and the environment

ANSTO capability/instrument

Australian Synchrotron
MX2
Macromolecular Crystallography

Collaborators/clients

- CSIRO
- Australian National University

Paper DOI

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Image:
3D model of PETase enzyme from *I. sakaiensis* (white) overlaid onto heat resistant ancestral PETase (green). Red highlights PET breakdown site. Orange highlights enzyme differences.

Image credit: Dr Chris Szeto

Converting waste into essential materials

THE CHALLENGE

As technologies and populations boom, global sustainability problems emerge. Industry must not only meet the increased demand for resources but also mitigate and minimise the resulting waste. In a circular economy, when waste is repurposed to produce essential materials, it addresses the demand for resources and reduces garbage. The processing of waste materials faces significant challenges, as materials arrive preformed, unreactive or contaminated. Two examples include the abundance of disused tires and plastics, and an increasing need for battery materials and catalysts for water purification and other processes. Researchers at the University of Adelaide and UNSW have investigated ways to effectively convert these waste materials into high-quality components, that require an understanding of what is happening in materials at every stage of the process.

THE SOLUTION

Researchers at UNSW have developed a method of processing old tires into electrodes for batteries. This required varying conditions, such as heat, moisture and air, to minimise impurities in the processed tires before incorporating the material into batteries and optimising their performance. The Soft X-ray (SXR) beamline was used to characterise the battery materials to understand what properties led to the best performance. Similarly, researchers from Adelaide developed a new way to convert old plastic into catalysts with a wide range of applications, from battery materials to water purification. Using X-ray Absorption Spectroscopy (XAS), they demonstrated that catalysts had a very subtle structural difference, which made a huge increase in their performance. Synchrotron techniques are powerful tools for understanding the structure of materials, because they reveal details about the materials that cannot be gained using other methods.

THE IMPACT

The generation of waste and electrical energy production are aspects of the modern world. Using the byproducts of one to satisfy the demands of the other could be the key to a more sustainable world. This research provides a route to this future. Australia discards 3.5 million tonnes of plastic and 50 million tires each year, as battery consumption continues to increase. Linking these streams presents a huge opportunity, opened up by the power of synchrotron science.



Australian Research Priority or Futures Made in Australia Framework

- Transitioning to a net zero future

ANSTO strategic priority

- Deliver on Australia's priorities for the benefit of people, industry and the environment

ANSTO capability/instrument

Australian Synchrotron
SXR
Soft X-ray spectroscopy
XAS
X-ray absorption spectroscopy

Collaborators/clients

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- Prof. Xiaoguang Duan, University of Adelaide
- Prof. Neeraj Sharma, University of New South Wales

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Paper DOI

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Dating ancient rock art and landscape evolution in the Kimberley

THE CHALLENGE

The Kimberley holds one of the world's richest records of Indigenous rock art. It embodies a cultural landscape of immense significance to Traditional Owners and to Australia. Yet its age has been almost impossible to determine. Because the paintings were made with mineral ochre, which contains no carbon, they cannot be dated with radiocarbon. Until recently, there was no way to date when sections of the rock shelters with the art on the surface had collapsed. Without those dates, neither the art nor the landscape around it could be placed in a time line.

THE SOLUTION

Mud wasps build nests on the rock walls, and those nests trap micrograms of charcoal that were radiocarbon dated using ultra-sensitive accelerator mass spectrometry. A nest beneath a painting must be older than the art; a nest laid over must be younger. The two brackets reveal the window when the work was done. To date when a shelter roof collapsed, the team used accelerator mass spectrometry to count beryllium-10 atoms that form in rock only while it is exposed to cosmic rays. Recently exposed surfaces inside a collapsed shelter carry less beryllium-10 than slabs outside the shelter that are exposed for long periods. Measurements of collapses spanning a few hundred thousand to about ten thousand years show the process is continuous. Together, the two clocks place the art and shelters in time.

THE IMPACT

The Kimberley rock art was placed on a firm timeline for the first time. The oldest art is at least 20,000 years old. A companion study measuring beryllium-10 in river sands across the region's catchments shows the landscape lowering by only a few metres every few million years. This represents some of the slowest erosion on Earth, which explains why ancient art survives. Being able to date shelter collapse improves the search for older art. The work provides Traditional Owners and heritage managers with firm dates to guide conservation and affirms the great antiquity of Indigenous culture.





Australian Research Priority or Futures Made in Australia Framework

- Protecting and restoring Australia's environment
- Elevating Aboriginal and Torres Strait Islander knowledge systems

ANSTO strategic priority

- Deliver on Australia's priorities for the benefit of people, industry and the environment

ANSTO capability/instrument

Centre for Accelerator Science
ANTARES 10MV Accelerator
SIRIUS 6MV Accelerator
Microgram Radiocarbon
Cosmogenic Exposure Dating

Collaborators/clients

- Kimberley Foundation Australia
- Balanggarra Aboriginal Corporation
- ARC-Linkage Funding
- Uni Melbourne
- Uni Western Australia
- Uni of Wollongong
- Dunkeld Pastoral Company

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Image:
(A) A Kimberley rockshelter with collapsed ceiling slabs, dated by cosmic-ray surface exposure.

(B) Close-up of the red kangaroo rock art motif with remnants of silicified wasp nests.

Ensuring trust in food origin using environmental fingerprints

THE CHALLENGE

Imagine paying a premium for authentic Australian produce, only to discover it isn't what it claims to be. Food fraud is a growing global problem, costing up to $50 billion USD annually and an estimated $2–3 billion AUD in Australia alone. It undermines consumer trust, damages reputable producers, and compromises food safety. For regulators and industry, the challenge is clear: how can they reliably prove where food truly comes from? In complex global supply chains, distinguishing local from imported, or wild from farmed, is not straightforward. Without robust verification methods, even high-value products remain vulnerable to mislabelling and fraud.

THE SOLUTION

ANSTO tackled this challenge by unlocking the atomic level information in food. Every product carries a unique chemical fingerprint, its isotopic and elemental signatures shaped by the environment in which it was grown. By decoding these patterns, ANSTO developed an advanced provenance technology that can accurately determine the geographic origin of food. The approach combines nuclear analytical techniques, fingerprint databases and AI-driven machine learning to create a robust, tamper-resistant method for authentication. To support real-world applications, ANSTO introduced two complementary capabilities: high-precision laboratory analysis to build trusted reference datasets and portable handheld XRF tools for rapid field testing. These methods have been successfully applied to authenticate the origins of seafood, the high-value native Australian fruit Kakadu plum, bulb vegetable and Great Barrier Reef coral systems. The result is clear: food origin can now be verified with high confidence across complex supply chains.

THE IMPACT

This work is transforming how food authenticity is verified in Australia and globally. It enables high-accuracy origin verification, strengthening trust in premium products and protecting industry value. The ability to test in real time using handheld XRF tools brings authentication directly into supply chains, improving responsiveness and reducing fraud risks. The approach also safeguards Indigenous products, supporting provenance and cultural integrity, while enhancing regulatory oversight and compliance. Beyond its immediate applications, this work provides new scientific insights into geochemical variability, establishing a robust foundation for reliable, data-driven provenance verification across diverse food systems while advancing food security and strengthening consumer trust.



Australian Research Priority or Futures Made in Australia Framework

- Protecting and restoring Australia's environment
- Elevating Aboriginal and Torres Strait Islander knowledge systems

ANSTO strategic priority

- Deliver on Australia's priorities for the benefit of people, the environment and industry

ANSTO capability/instrument

X-ray Florescence scanning (ITRAX) and hand held
IRMS (Stable Isotopes)

Collaborators/Clients

- Department of Agriculture Fisheries and Forestry (DAFF)
- Sydney Fish Market
- NSW Department of Primary Industry (Fisheries)
- National Measurement Institute (NMI)
- Northern Australia Aboriginal Kakadu Plum Alliance (NAAKPA)
- Department of Climate Change, Energy, The Environment and Water (DCCEEW)
- University of New South Wales
- Macquarie University

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Image:
Animals and plants take in elements and isotopes from their environment, that form a detectable environmental fingerprint.

Improving green hydrogen production

THE CHALLENGE

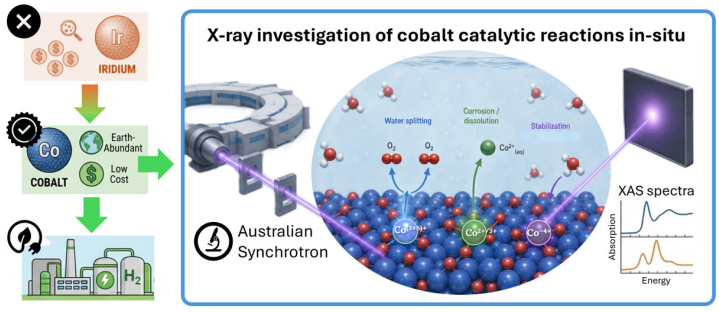
Renewable hydrogen using proton exchange water electrolysis is a lead contender to support the decarbonisation of energy-intensive industries. However, widespread adoption of the technique requires improvements in efficiency, stability, and affordability of electrocatalysts. The scarcity and expense of high-performing catalysts such as iridium have driven intense interest in more abundant alternatives. Cobalt-based oxides show promising behaviour for half of the water-splitting reaction; yet they suffer from rapid degradation and loss of active sites in the acidic environments required for the reaction. To overcome this performance barrier, more must be understood on how the corrosion is fundamentally tied to the oxygen evolution catalytic reaction.

THE SOLUTION

Using advanced synchrotron spectroscopy and electrochemical techniques, researchers studied a cobalt–iron–lead oxide material under real operating conditions. They tracked changes in the oxidation state and chemical structure during water splitting. They discovered that the catalytic reaction occurs simultaneously but independently to the surface corrosion and degradation that leads to the reduced lifetime of the catalyst. These observations and other activities that help stabilise the surface provide potential pathways to reduce the surface degradation of cobalt catalysts.

THE IMPACT

This work provides a completely new interpretation of the chemical processes happening on the cobalt surface and reframes how catalyst stability should be addressed. Since degradation is not intrinsically linked to the catalytic reaction, research to extend catalyst lifetimes can focus on how to preserve active sites through controlled redeposition or surface stabilisation. This paves the way for cobalt-based alternatives to iridium in proton exchange membrane electrolysers, which will reduce costs and accelerate the deployment of large-scale green hydrogen technologies critical for global decarbonisation.



Australian Research Priority or Futures Made in Australia Framework

- Transitioning to a net zero future
- Building a secure and resilient nation

ANSTO strategic priority

- Use of national research infrastructure
- Deliver on Australia's priorities for the benefit of people, industry and the environment

ANSTO capability/instrument

Australian Synchrotron
XAS
X-ray Absorption Spectroscopy

Collaborators/clients

- Monash University
- Swinburne University of technology
- University of Wollongong
- Max Plank Institute
- Los Alamos Laboratory
- University of Cambridge
- Helmholt-Zentrum Berlin for Materials and Energy

ANSTO contributors

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Paper DOI

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Image:
Infographic showing how synchrotron light has been used to probe the cobalt surface in-situ during acidic water oxidation. X-ray absorption spectroscopy data revealed the simultaneous but independent corrosion and catalysis reactions, giving new understanding which can be used to engineer durable earth-abundant catalysts for cheaper green hydrogen production.

Machine learning cuts air pollution analysis from hours to seconds

THE CHALLENGE

ANSTO works out what is in air pollution by firing an ion beam at filter samples and reading the X-rays that come back. Converting a measurement into a list of elements and their amounts relies on detailed physics modelling. It is accurate, but slow, computationally heavy and easily disturbed by small imperfections in the equipment. As the Aerosol Sampling Program runs thousands of these filters for regulators and industry, this step became the bottleneck. Results were delayed and accelerator time was tied up. With demand growing for national scale monitoring, a faster route to the same numbers was needed.

THE SOLUTION

The team trained machine learning models on more than 3,500 measurements from program filters over five years under consistent conditions. Given enough examples, the models learn the relationship between the shape of a raw spectrum and the elements that produced it, so they could report concentrations from hydrogen to lead without the physics calculations in seconds rather than hours. The models also work in reverse: from a set of known concentrations, they reconstruct a complete, realistic spectrum. That reverse mode lets researchers simulate a measurement before running it and judge whether a planned sample would be detectable at all. As the predictions track the conventional fitted results closely, the two approaches can be used together rather than one replacing the other.

THE IMPACT

As results now reach regulators and industry far faster, pollution sources can be identified while the information is still useful for decisions. Problems show up during a run rather than weeks later. It lets the team catch inconsistent data immediately and avoid wasting accelerator time. Being able to simulate a measurement in advance means experiments can be screened and designed before beam time is committed. Together, these changes make national scale air pollution monitoring practical, because throughput is no longer limited by how quickly the physics modelling can be run.

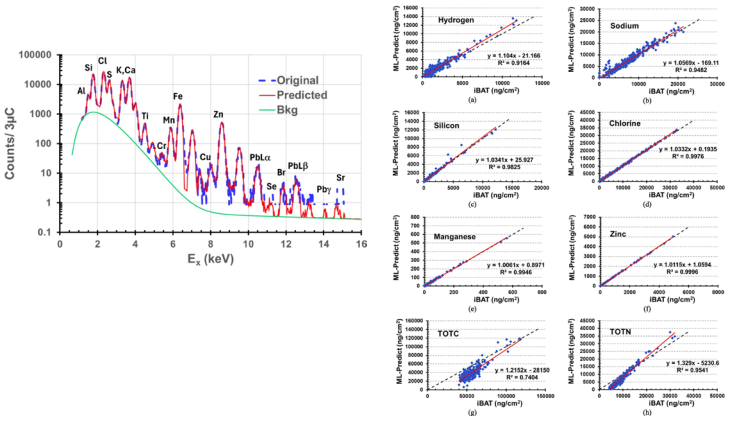

Image:
(A) Measured and machine-learning-predicted X-ray spectra for a typical fine particle (PM2.5) air pollution sample. (B) Machine-learning predictions compared with conventional fitted analysis for chlorine.

Australian Research Priority or Futures Made in Australia Framework

- Protecting and restoring Australia's environment

ANSTO strategic priority

- Deliver on Australia's priorities for the benefit of people, industry and the environment

ANSTO capability/instrument

Centre for Accelerator Science
STAR 2MV accelerator
Ion beam analysis
Aerosol Sampling Program

Collaborators/clients

- NSW Department of Climate Change, Energy, the Environment and Water

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- Francesca Wilkins
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Measuring cleaner air as fossil fuel power stations close

THE CHALLENGE

Fine airborne particles, small enough to pass from the lungs into the bloodstream, worsen the risk of heart and lung disease. Some of them form in the atmosphere out of sulfur dioxide, a gas released when coal is burned. Coal-fired power stations have historically produced about 85% of sulfur dioxide emissions in New South Wales, according to the state's Environment Protection Authority. Twelve of those stations have closed since the 1990s, and the last four are due to shut by 2040. Whether that shift has actually made the air measurably cleaner is a question only decades of consistent measurement can answer.

THE SOLUTION

For more than thirty years, ANSTO's Aerosol Sampling Program has collected fine particles on filters at sites across New South Wales and identified their contents. Ion beam analysis can identify the elements in each filter, which is then used to calculate the amount of ammonium sulfate within it. That compound is a useful tracer. Because it forms in the atmosphere out of sulfur dioxide gas, its level follows what the power stations emit. The amount of ammonium sulfate fell from roughly 25 micrograms per cubic metre in the 1990s to roughly 1 microgram per cubic metre in the 2020s. This was a period when there were twelve plant closures. Total fine particle levels have also fallen with fewer days above the national health standard. The record shows the move away from coal is reflected in the air itself.

THE IMPACT

ANSTO's Aerosol Sampling Program gives regulators and policy makers something rare: an unbroken, independently measured record of what the energy transition has done to the air people breathe. Because the same methods have been used since the 1990s, changes across decades can be compared with confidence rather than inferred. That evidence informs decisions on emission controls and closure timetables and sets a baseline against which the final four closures can be evaluated. Lower fine particle levels reduce a known risk factor for heart and lung disease across the New South Wales population.

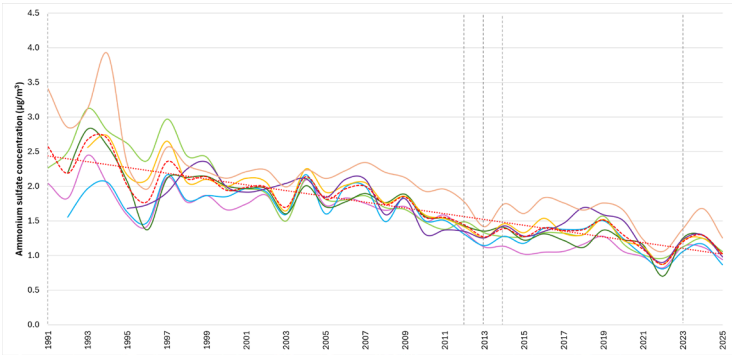

Image:
The figure (left) displays measured ammonium sulfate concentrations at (7) ANSTO Aerosol Sampling Program sites across New South Wales since 1991. The red dashed lines represent the overall annual mean concentration and the downward trend in measured ammonium sulfate levels. The grey dashed lines indicate years where a coal-fire power station decommissioning has occurred.

Australian Research Priority or Futures Made in Australia Framework

- Transitioning to a net zero future
- Supporting healthy and thriving communities
- Protecting and restoring Australia's environment

ANSTO strategic priority

- Deliver on Australia's priorities for the benefit of people, industry and the environment

ANSTO capability/instrument

Centre for Accelerator Science
STAR 2MV accelerator
Ion beam analysis

Collaborators/clients

- NSW Environment Protection Authority
- Department of Climate Change, Energy, the Environment and Water

ANSTO contributors

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Paper DOI

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Reading the history of Antarctic ice to understand climate change

THE CHALLENGE

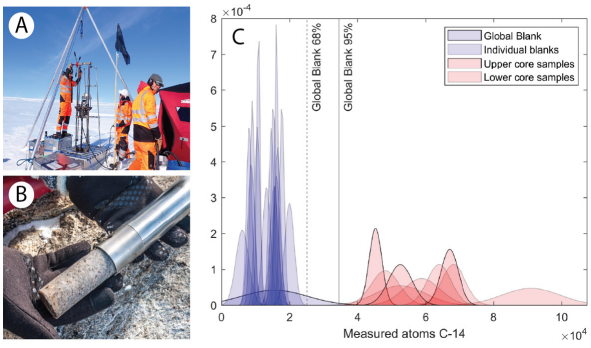
How much will seas rise as Antarctica's ice melts? Prediction models can only be trusted if they reproduce the past accurately. Scientists need a reliable record of when the ice sheet thinned, retreated and regrew over recent millennia. The standard method dates rock surfaces by measuring beryllium-10, an atom that cosmic rays create in exposed rock, with a signal that can survive long burial beneath frozen ice. Old exposure then masquerades as new; recent ice loss looks older and slower than it was. Scientists needed a way to date recent change directly, even in rock still buried under ice.

THE SOLUTION

The answer is found in measurements of radiocarbon found in rocks. Cosmic rays also create radiocarbon in exposed rock but it decays away much faster than beryllium-10, within tens of thousands of years. Deep burial erases the old signal, so any radiocarbon in rock beneath the ice today means that rock was uncovered recently. The team extracted the cosmogenic radiocarbon atoms from quartz in Antarctic bedrock, drill cores and boulders. They then counted them individually using ultra-sensitive accelerator mass spectrometry at ANSTO's Centre for Accelerator Science. In the Weddell Sea region, radiocarbon in rock now under ice showed the ice surface sat at least 20 metres lower than today for centuries to millennia within the last 6,000 years. At Scott Glacier in East Antarctica, the same approach revealed about 50 metres of thinning between roughly 10,700 and 7,700 years ago. The results turn ambiguous dates into direct evidence that parts of the ice sheet thinned below today's level and later regrew.

THE IMPACT

These dates give modellers hard benchmarks. An ice-sheet model that cannot reproduce the measured thinning and regrowth cannot be trusted to project future sea-level rise. Researchers now compare records directly with satellite observations and sharpen the forecasts that coastal communities, including Australia's, depend on. The measurement itself is extraordinarily difficult. Each Weddell Sea sample held fewer than 100,000 radiocarbon atoms. This is only slightly above the background measurements. However, the world-leading facilities at ANSTO's Centre for Accelerator Science made it possible to tell the difference. This sovereign capability is strategically important to international Antarctic research and the global climate science community.



Australian Research Priority or Futures Made in Australia Framework

- Protecting and restoring Australia's environment
- Transitioning to a net zero future
- Securing Antarctica's Environmental Future

ANSTO strategic priority

- Deliver on Australia's priorities for the benefit of people, industry and the environment

ANSTO capability/instrument

Centre for Accelerator Science
6MV SIRIUS Accelerator
Accelerator Mass Spectrometry
10MV ANTARES Accelerator
In-situ cosmogenic micro radiocarbon

Collaborators/clients

- A/Prof David Small, Durham University
- Dr Richard Jones, Monash University
- Mr Gianluca Borraccini, University of Pisa
- Securing Antarctica's Environmental Future (SAEF)

ANSTO contributors

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- Dr Bin Yang
- Dr Andrew M. Smith
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Paper DOI

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Image:
(A) Coring bedrock beneath ice, (B) recovered core, (C) carbon-14 in samples versus background. Image credit: D. Small and R. Jones. Adapted from Small et al. (2026). Reprinted under Creative Commons License 4.0. https://creativecommons.org/licenses/by/4.0/. Small *et al., European Geosciences Union* (2026).

Safely decommissioning offshore infrastructure

THE CHALLENGE

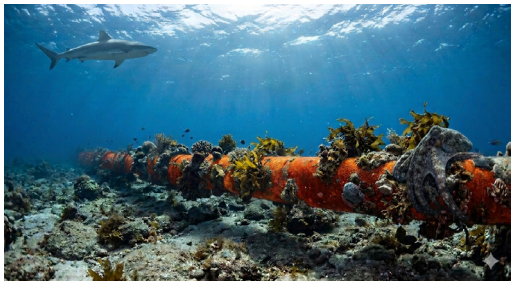
Australia is one of the largest exporters of natural gas globally, with a substantial proportion of oil and gas being extracted offshore from our continental shelf. At the end of operational life, all infrastructure is required by law to be removed unless a case can be made that the risks are as low as reasonably achievable. Contaminants on the internal surfaces of production infrastructure (such as pipelines), including naturally occurring radioactive material (NORM) and mercury, may represent a risk to Australia's marine ecosystem that should be assessed before impacted infrastructure can be left on the seabed.

THE SOLUTION

ANSTO is leading research to characterise contaminants from oil and gas production. This is improving our understanding of how such contaminants behave in Australia's marine environment, and how they may interact with and potentially impact Australia's marine ecosystem and fisheries. This is achieved through two scientific pathways: 1) using cutting-edge nuclear science based testing capabilities in specialist laboratories at ANSTO to provide a detailed understanding of the concentrations, chemistry and composition of contaminants to capture potential leaching in seawater and potential bioavailability and 2) using bespoke radioisotope tracers of mercury produced using the OPAL research reactor to understand the potential chemical transformations and bioaccumulation of mercury by Australian marine organisms. This information guides an informed assessment of ecological risk and allows for robust environmental management decisions to be made.

THE IMPACT

Research findings and analytical testing results have been used by both industry and government stakeholders to provide critical information about the long-term impacts of residual contaminants from decommissioned subsea pipelines. Industry can better plan their decommissioning process, while regulators can accurately assess potential impacts of contaminants within offshore infrastructure. The team has co-developed a contaminant risk assessment framework specific for Australian offshore infrastructure and has worked with international bodies, including the IAEA, to develop technical reports outlining best practice management of NORM-contaminated production infrastructure.



WATCH THE VIDEO

Australian Research Priority or Futures Made in Australia Framework

- Protecting and restoring Australia's environment

ANSTO strategic priority

- Deliver on Australia's priorities for the benefit of people, industry and the environment

ANSTO capability/instrument

OPAL
Vivarium
Australian Synchrotron
XFM
X ray Fluorescence Microscopy
XAS
X ray Absorption Spectroscopy

SEM, TEM
Gamma & Alpha Spectrometry
CV-AFS

Collaborators/clients

- Multiple Industry partners
- NOPSEMA, DCCEEW and DISR
- Australian Institute of Marine Science (AIMS)
- La Trobe University
- Australian National University

ANSTO contributors

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- Dr Alexandra Boyd
- Minerals
- Radiation Services

Paper DOI

doi.org/10.2139/ssrn.6591352

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Image:
AI generated image of a subsea oil and gas pipeline. (Google Gemini)

Source of powerful greenhouse gas revealed

THE CHALLENGE

Methane is a powerful greenhouse gas, that is responsible for roughly a third of global warming. Wetlands are the largest natural source of methane. Research had assumed the gas escaped mainly from sediments and open water. Then came a surprise. The trees vent methane through their trunks in amounts large enough to matter for national and global greenhouse gas accounts. However, no one had identified the source of the carbon in that methane. If it were ancient carbon locked in deep soil, emissions would signal the slow release of long-buried stores and it would behave quite differently from methane made in topsoil.

THE SOLUTION

Carbon carries its own clock. Radiocarbon decays at a known rate, so the older the carbon, the less remains, and measuring what is left dates the source. The team sampled gas from paperbark trunks in a subtropical forested wetland in northern New South Wales, along with gas bubbling from the sediment, soil from a range of depths and cores from the trees. At ANSTO, a dedicated facility separated and purified the methane, which was then measured on accelerators that count carbon atoms individually. The methane leaving the trunks carried the same radiocarbon signature as shallow soil, and far less than the wood of the trees themselves. The trees are acting as chimneys for methane made in the topsoil, not releasing ancient carbon or producing methane inside their own trunks.

THE IMPACT

Because the carbon is recent, these emissions will track short-term changes in rainfall, water levels, plant growth and disturbances, rather than the slow release of ancient soil stores. That makes them far more predictable, and it identifies which processes need representation in models. Forested wetlands are handled crudely in global methane budgets and Earth system models, but these measurements provide a firmer foundation for analysis. The approach is also transferable. The same radiocarbon method can now trace the age and source of methane across other wetlands and tree species.



Australian Research Priority or Futures Made in Australia Framework

- Protecting and restoring Australia's environment
- Transitioning to a net zero future

ANSTO strategic priority

- Environment & Energy

ANSTO capability/instrument

Centre for Accelerator Science
ANTARES 10 MV accelerator
VEGA 1 MV accelerator
Carbon dioxide and methane gas processing line
Microgram-size radiocarbon analysis

Collaborators/Clients

- Dr Luke Jeffrey, Southern Cross University
- Prof Damien Maher, Southern Cross University

ANSTO contributors

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- Dr Quan Hua
- Dr Bin Yang

Paper DOI

doi.org/10.21203/rs.3.rs-10147668/v1

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Image:
Paperbark trees in the subtropical forested wetland in northern New South Wales where tree stem methane was sampled. Reprinted under Creative Commons License 4.0. https://creativecommons.org/licenses/by/4.0/. Jeffrey *et al., Research Square, under review, Nature Portfolio* (2026).

Stalagmites reveal groundwater replenishment rates at an 800-year low in southwest Australia

THE CHALLENGE

Groundwater is a critical water resource for southwest Western Australia, as it supplies Perth and many regional communities. Since the late 1960s, the region has experienced a significant decline in rainfall, raising concerns about the long-term sustainability of groundwater resources. However, direct observations of groundwater recharge are relatively short, making it difficult to determine whether recent changes are exceptional or part of natural climate variability. The challenge was to develop a reliable long-term record of groundwater recharge and assess how reduced rainfall has affected the replenishment of aquifers over centuries.

THE SOLUTION

Researchers used a world-first approach that combined analyses of cave drip waters and seven stalagmite records from four cave systems in southwest Western Australia. Stalagmites preserve environmental information through their chemical composition and provide a natural archive of groundwater recharge over time. By comparing modern dripwater measurements with stalagmite records extending back approximately 800 years, the team reconstructed long-term changes in rainfall recharge to shallow karst aquifers. Using an oxygen isotope, the study found a pronounced recent increase in measurements that could only be explained by a reduced connection between rainfall and groundwater recharge driven by prolonged regional drying. The research concluded that groundwater recharge in southwest Western Australia has declined substantially and that current recharge levels are lower than at any time in at least the past 800 years. This provides new evidence that climate-driven drying is fundamentally altering groundwater replenishment processes.

THE IMPACT

The study provides the first long-term evidence that rainfall recharge to groundwater in southwest Western Australia has reached an unprecedented low—strengthening understanding of climate change impacts on water security. It delivers a novel palaeoclimate tool for reconstructing groundwater recharge from cave deposits with applications in Australia and internationally. The findings support evidence-based water-resource planning by highlighting the vulnerability of groundwater-dependent communities, ecosystems and industries to ongoing drying trends. By demonstrating that groundwater recharge may no longer reliably occur under current climatic conditions, the research informs adaptation strategies for managing water supplies in a changing climate.



Australian Research Priority or Futures Made in Australia Framework

- Protecting and restoring Australia's environment

ANSTO strategic priority

- Deliver on Australia's priorities for the benefit of people, industry and the environment

ANSTO capability/instrument

ICP-MS
ICP-AES
IC
IRMS Stable isotopes

Centre for Accelerator Science
ANTARES 10 MV Accelerator

Australian Synchrotron
XFM
X-ray fluorescence microscopy

Collaborators/clients

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- Prof Andy Baker, University of NSW

ANSTO contributors

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- Dr Karina Meredith

Paper DOI

doi.org/10.1038/s43247-023-00858-7

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Image:
Sampling cave dripwaters

Synchrotron science supports research for cleaner water

THE CHALLENGE

Clean water is essential for human health, yet modern water systems face two growing threats: persistent chemical pollutants and harmful bacteria. Emerging contaminants from industry, pharmaceuticals and consumer products can resist conventional treatment processes, while antimicrobial-resistant microbes can survive disinfection and spread through water networks. Developing new materials that can efficiently remove both chemical and biological contaminants is therefore a major global challenge. However, designing these materials requires understanding exactly how they interact with pollutants and microorganisms at the molecular level—information that is often invisible to conventional analytical techniques.

THE SOLUTION

Two advanced spectroscopy techniques at the Australian Synchrotron were used to investigate next-generation materials designed to improve water quality.

Using infrared microspectroscopy, scientists from Adelaide University tracked chemical reactions in real time as a newly engineered catalyst broke down persistent organic pollutants. The measurements revealed how the catalyst activates oxidants and rapidly removes contaminants through an efficient, low-cost pathway.

Researchers from Griffith University examined antibacterial zinc oxide coatings developed to combat harmful waterborne bacteria using X-ray Absorption Spectroscopy (XAS). XAS measurements revealed the atomic structure and chemical state of the active forms of zinc, which helped explain why the material effectively suppresses bacterial growth.

Together, these complementary synchrotron insights linked material structure with performance and provided critical knowledge to guide the design of more effective technologies for removing chemical pollutants and biological contaminants from water.

THE IMPACT

For the first time, researchers could directly observe how advanced materials tackle two major threats to water quality: persistent chemical pollutants and harmful bacteria. These insights are helping scientists design more effective, lower-cost water treatment technologies that are safer and more sustainable.

The outcomes could improve wastewater purification, reduce the spread of antimicrobial-resistant microbes, and support cleaner waterways and drinking water supplies.



Australian Research Priority or Futures Made in Australia Framework

- Supporting healthy and thriving communities

ANSTO strategic priority

- Use of national research infrastructure
- Deliver on Australia's priorities for the benefit of people, industry and the environment

ANSTO capability/instrument

Australian Synchrotron
IRM
Infrared Microspectroscopy
XAS
X-ray Absorption Spectroscopy

Collaborators/clients

- Professor Xiaoguang Duan, Adelaide University
- Professor Shaobin Wang, Adelaide University
- A/Professor Adam F. Lee, Griffith University
- A/Professor James Chapman, Griffith University

ANSTO contributors

- Dr. Pimm Vongsvivut
- Dr. Bernt Johannessen

Paper DOI

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Transforming industrial waste into new products

THE CHALLENGE

Globally, there is an increasing need for environmentally sustainable and energy-efficient industrial practices. Fossil-fuel generated electricity is driving up carbon dioxide emissions while the production of ammonia and urea, vital chemicals for food production, still rely on energy-intensive processes. As well as increasing industrial energy efficiency, it is also critical to be able to convert chemical waste streams and carbon emissions into useful chemicals. The development of advanced materials for energy conversion and catalysis can be achieved using synchrotron techniques.

THE SOLUTION

Researchers from the University of New South Wales in collaboration with partner institutions have used advanced synchrotron techniques on multiple beamlines at the Australian Synchrotron to deliver insights into new catalysts and advanced composite materials. These materials can convert industrial waste products into useful commodities. A mixed-metal organic framework has efficiently converted CO_2 into methane and carbon monoxide. Recently, investigators have also made advancements in producing ammonia for solar power and the synthesis of urea for fertilisers. A nanostructured 'artificial leaf' system combining silicon solar panels with engineered nanomaterials was shown to directly convert toxic nitrate wastewater into ammonia with almost 100% efficiency. A novel copper-cobalt nanowire catalyst was shown to efficiently convert CO_2 and nitrate into urea. Synchrotron techniques provided a range of complementary techniques to reveal atomic-scale chemical and structural information that is essential for understanding, optimising and scaling the materials for waste stream conversion.

THE IMPACT

Development of advanced catalyst materials offers a pathway to a greener, more circular industrial economy. Understanding how these materials behave under real-world operating conditions requires multiple methods to investigate chemistry and structure at the atomic level. Australian researchers have access to a range of advanced spectroscopic techniques at the Australian Synchrotron for their research. With this data, researchers can further refine and improve catalyst efficiency and stability and improve methods for industrial level use to support Australia's clean industry goals.

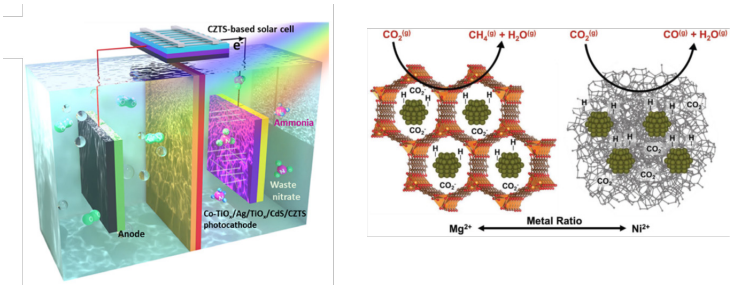

Image:
Photochemical cell for ammonia synthesis from waste nitrate (left), and an advanced mixed metal organic framework nanomaterial for conversion of CO_2 to CO and methane (right).

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Australian Research Priority or Futures Made in Australia Framework

- Transitioning to a net zero future

ANSTO strategic priority

- Use of national research infrastructure
- Deliver on Australia's priorities for the benefit of people, industry and the environment

ANSTO capability/instrument

Australian Synchrotron
IRM
Infrared Microspectroscopy
SXR
Soft X-ray Spectroscopy
XAS
X-ray Absorption Spectroscopy

Collaborators/clients

- University of New South Wales
- Adelaide University
- Curtin University
- CSIRO

ANSTO contributors

- Dr Anton Tadich
- Dr Bernt Johannessen
- Dr Pimm Vongsvivut

Paper DOI

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doi.org/10.1016/j.apcatb.2024.123836

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Nuclear applications

Nuclear science and technology support a safe and sustainable nuclear industry

Australia's nuclear capability at ANSTO is a nationally significant and strategic asset. With trusted expertise, world-class infrastructure and enduring international partnerships, ANSTO enables Australia to address increasingly complex challenges while delivering scientific, economic and societal benefits.

Australia's nuclear credentials at ANSTO are built on decades of technical excellence, strong governance and international cooperation. This has made us a trusted and reliable partner supporting the peaceful uses of nuclear technologies, nationally and internationally.

ANSTO provides trusted advice to inform decision-making by government, industry and researchers and supports national resilience and capabilities by maintaining skills, infrastructure and knowledge in nuclear science and technology that are critical to Australia's future.

ANSTO research in nuclear materials and technology supports more efficient use of nuclear fuel and targets. It provides a detailed understanding of microstructural and mechanical properties of materials, particularly in extreme environments such as reactors, supporting more effective design of structures, and it develops solutions for handling radioactive waste and materials.

Our expertise is also used in applications of nuclear technologies, such as the development of radiation detectors, and to support our nuclear stewardship activities, including the impacts of nuclear technologies and nuclear security and safeguards.

Building on more than 50 years of research experience applied to industrial problems in the areas of uranium, rare earth and lithium processing, ANSTO is also a global leader in the processing of critical and strategic metals. We have a proven track record, in Australia and internationally, of providing practical solutions that deliver measurable financial and environmental benefits to the mining and minerals processing industry.

Advanced neutron imaging technology supports nuclear safeguards and security

THE CHALLENGE

Gamma-ray imaging systems have been used for decades with ongoing advances such as ANSTO's CORIS360® technology improving performance, reliability and applications. Neutron imaging, however, introduces additional complexity due to the unpredictable ways neutrons interact with and move through materials.

Neutrons are present in many nuclear settings, including reactor operations, nuclear material characterisation and spent nuclear fuel management. Effective neutron detection and imaging are important for nuclear security, safeguards and radiation protection applications. Continued advances in neutron detection and imaging have the potential to strengthen capabilities across these domains.

THE SOLUTION

Drawing on the patented core technology of the innovative CORIS360® platform, the CORIS360® Gamma Neutron Imager (GNI) is the first in-market solution to detect, identify and localise nuclear materials through both gamma-ray and thermal neutron signatures.

This was achieved through modification of the instrument's mask design and materials. The mask is a critical component that selectively modulates the radiation signal during measurement, thereby enabling rapid image reconstruction.

The CORIS360® GNI system overlays gamma-ray and neutron images onto a 360° optical panorama of the surrounding area, providing an easy-to-interpret visualisation of radiation source locations.

THE IMPACT

The CORIS360® GNI represents a significant advancement by locating and imaging radiation from thermal neutron sources while retaining gamma-ray imaging capability. It supports applications in nuclear safeguards, nuclear disarmament verification and radiation safety.

The CORIS360® platform supports improved operational decision-making, risk reduction and enhanced safety by identifying and imaging radiation source locations. These capabilities assist personnel working in radioactive environments, support non-proliferation activities and contribute to improved radiation protection outcomes.



Australian Research Priority or Futures Made in Australia Framework

- Building a secure and resilient nation

ANSTO strategic priority

- Deliver on Australia's priorities for the benefit of people, industry and the environment
- Australia's source of nuclear expertise, advice and services
- Lead the development of nuclear capable workforce

ANSTO capability/instrument

Detection and Imaging
Instrument Calibration Facility

ANSTO contributors

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- Dr Lachlan Chartier
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- Feiming Lu
- Jason Christoforodis

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Image:
The CORIS360® GNI technology

Advancing wasteforms for long-term radioactive waste management

THE CHALLENGE

Long-lived radioactive wastes containing uranium, actinides and other hazardous elements remain a significant international challenge with many waste streams lacking established disposal pathways. As Australia's producer of nuclear medicines, ANSTO is seeking sustainable treatment pathways for uranium-bearing radiopharmaceutical wastes while continuing to advance and commercialise ANSTO Synroc® wasteform technology. Although zirconolite is recognised as one of the most durable materials for actinide immobilisation, conventional ceramic wasteforms can be challenging to process and there is limited ability to predict the long-term behaviour of complex materials. Improved wasteforms and greater confidence in disposal performance were needed.

THE SOLUTION

ANSTO developed and optimised a new generation of zirconolite glass-ceramic wasteforms by combining durable zirconolite crystals with engineered glass matrices. This glass-ceramic approach combines the chemical durability of zirconolite with the processing flexibility of glass, enabling high actinide incorporation, improved densification and reduced processing temperatures. Using advanced synthesis, microscopy, diffraction and microstructural characterisation techniques, ANSTO and University of UNSW researchers identified compositions that effectively partitioned actinide surrogate elements into zirconolite. The work expanded through major collaboration with Pacific Northwest National Laboratory to investigate wasteform behaviour and develop novel predictive models for complex wasteforms. To better understand the factors controlling durability, ANSTO also developed new methodologies capable of accurately characterising grain size, phase distribution and crystallographic relationships in these zirconolite-containing wasteforms. The research demonstrated that wasteform performance can be linked to phase chemistry and microstructure, providing the scientific foundation needed to support future wasteform engineering and deployment.

THE IMPACT

This work provides the technical basis for future treatment of ANSTO's uranium-bearing radiopharmaceutical wastes and advances ANSTO Synroc® wasteform technology for this and many other challenging actinide-containing waste streams worldwide that currently lack viable disposal solutions. The optimised zirconolite glass-ceramic wasteforms reduce processing requirements while associated corrosion testing, predictive modelling and grain-size characterisation methods improve confidence in long-term wasteform performance and repository safety. These capabilities provide the underpinning science required for future engineering implementation of advanced waste treatment solutions. The research has generated multiple peer-reviewed publications, a WM2026 Superior Paper Award and a WM2026 Best Oral Paper/Presentation and has contributed to advancing international multiphase wasteform science.

Australian Research Priority or Futures Made in Australia Framework

- Protecting and restoring Australia's environment.

ANSTO strategic priority

- Australia's source of nuclear expertise, advice and services

ANSTO capability/instrument

Advanced Materials Characterisation
ANSTO Synroc® Technology
Hot Isostatic Pressing (HIP)

Collaborators/clients

- University of New South Wales (UNSW)
- Pacific Northwest National Laboratory (PNNL), USA

ANSTO contributors

- Synroc Team
- Reactor Systems
- Actinide Science
- Australian Synchrotron

Paper DOI

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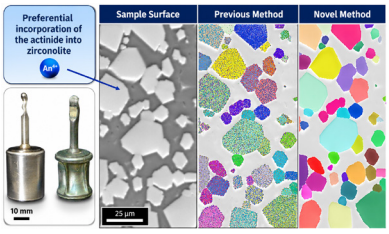

Image:
Advanced EBSD characterisation developed at ANSTO enabling accurate measurement of zirconolite grain size, phase distribution and crystallographic relationships.

An integrated characterisation pathway for the treatment and disposal of nuclear waste

THE CHALLENGE

Successful radioactive waste treatment depends on a detailed understanding of the chemical and radiological properties of both the waste being processed and the wasteforms produced. As ANSTO develops new waste treatment pathways, including operation of the ANSTO Synroc® Waste Treatment Plant, robust characterisation is required to support process design, plant commissioning, wasteform qualification and regulatory compliance. However, radioactive wastes often contain complex and variable mixtures of radioactive isotopes and chemicals, which require specialised analytical methods. To address these requirements, ANSTO developed a comprehensive integrated sampling and characterisation framework capable of supporting current and future waste treatment initiatives, long-term waste management strategies and repository requirements.

THE SOLUTION

This framework can be applied to both intermediate-level liquid waste and ANSTO Synroc® wasteforms produced by the new plant. The approach combined advanced chemical, radiological and materials characterisation methods to provide a complete understanding of waste composition throughout the treatment lifecycle. New analytical protocols were established to determine key process elements with great accuracy. Fission products were quantified and trace actinides were measured. Complementary analytical methods were also applied to assess the composition of the final wasteform, optimise processes, achieve quality assurance and comply with future waste acceptance requirements. The work established a unique suite of 'nuclearised' analytical capabilities and methodologies that are now being used in the new plant commissioning while providing a platform for future radioactive waste characterisation activities across ANSTO, including support for nuclear medicine production, OPAL operations and collaboration with the Australian Radioactive Waste Agency (ARWA).

THE IMPACT

This work established an integrated characterisation capability and framework that supports the commissioning and future operation of ANSTO's waste treatment while providing a foundation for future radioactive waste treatment programs across the organisation. The methodology delivers the detailed chemical and radiological information required for process design and development, process optimisation, wasteform qualification, quality assurance and repository acceptance. Radioactive waste streams cannot be adequately characterised through one-off measurements. The resulting framework has been documented in several foundational technical reports and has achieved international recognition through invited presentations and inclusion in the International Atomic Energy Agency's 2026 handbook on radioactive waste characterisation.

Australian Research Priority or Futures Made in Australia Framework

- Protecting and restoring Australia's environment
- Supporting healthy and thriving communities

ANSTO strategic priority

- Deliver on Australia's priorities for the benefit of people, industry and the environment
- Australia's source of nuclear expertise, advice and services

ANSTO capability/instrument

Active characterisation facilities
MFB and trace element lab

ANSTO contributors

- Synroc Team
- MFB Facility Staff
- Nuclear Medicine
- Waste Management Services

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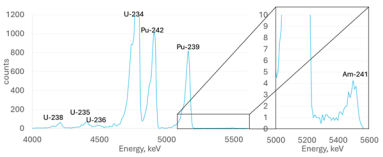

Image:
Analysis of actinides in ILLW. Measured Am-241 concentration is 0.39 ± 0.02 ppt.

Can seawater support more sustainable nuclear fuel?

THE CHALLENGE

To reduce climate change, the world needs reliable low-carbon energy. Nuclear power is one option overseas, but it depends on a supply of uranium, which is limited in land-based deposits. Seawater contains a huge supply of uranium, but extracting it is extremely difficult. The problem is scale and selectivity. Uranium exists in seawater at very low levels (about 3.3 micrograms per litre), while other elements, such as sodium and calcium, are present at much higher concentrations. This makes it difficult to design materials that can 'pick out' uranium efficiently without being overwhelmed by other ions.

THE SOLUTION

The team developed a new class of materials called layered double hydroxides (LDHs), which are low-cost and easy to produce. They modified these materials by adding small amounts of specific elements, known as dopants, including neodymium. This process, known as dopant engineering, changes how the material interacts with uranium. Using advanced X-ray techniques at the Australian Synchrotron, the researchers directly observed how uranium binds to the material at the atomic level. They showed that uranium attaches to surface sites, metal–hydroxide groups, and can also replace other ions within the structure of the material.

Importantly, adding neodymium improved the material's ability to favour uranium over competing elements like calcium. The study proves that carefully tuning a material's chemistry can greatly improve uranium selectivity and revealed, for the first time, how this process works under real seawater conditions.

THE IMPACT

The new material can selectively capture uranium from seawater with high efficiency, even in the presence of large amounts of competing elements. It performs as well as leading commercial materials but is cheaper and simpler to produce. This advances the possibility of extracting uranium at scale from seawater—providing a long-term and secure fuel supply for low-carbon nuclear energy. More broadly, the work shows how materials can be designed at the atomic level to selectively capture valuable elements and open new opportunities in clean energy, resource recovery and environmental protection.



Australian Research Priority or Futures Made in Australia Framework

- Transitioning to a net zero future
- Protecting and restoring the environment

ANSTO strategic priority

- Australia's source of nuclear expertise, advice and services

ANSTO capability/instrument

Australian Synchrotron
XAS
X-ray absorption spectroscopy
SXR
Soft X-ray spectroscopy

Collaborators/clients

- The University of New South Wales
- Illinois Institute of Technology, USA

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- Dr Daniel T. Oldfield
- Dr Lars Thomsen
- Dr Jessica L. Hamilton

Paper DOI

doi.org/10.1039/d3ya00154g

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Image:
Research was featured on the cover of the journal *Energy Advances*.

Developing national analytical capabilities for nuclear safeguards

THE CHALLENGE

Developing Australia's capabilities in analysing materials containing actinides is critical for the enhanced safeguarding of nuclear activities across the nuclear industry. Nuclear safeguards rely on advanced scientific methods to develop policies, methodologies and technologies to detect, deter and investigate the misuse of nuclear materials. These safeguards ensure that civilian nuclear materials and facilities are used exclusively for peaceful purposes.

Major capabilities being developed at ANSTO include the reliable preparation and characterisation of representative actinide-bearing materials, and the development of advanced analytical techniques to identify material 'fingerprint signatures', such as structure and microstructure, chemical composition, isotopic content and physical characteristics for relevant nuclear safeguards applications.

THE SOLUTION

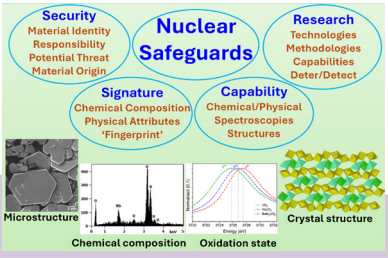
With funding from the Australian Non-proliferation Office (ASNO), the project is developing Australia's sovereign capability in the preparation, characterisation and analysis of actinide-bearing materials using a combination of ANSTO lab-based techniques coupled with neutron and synchrotron techniques. The combination of these advanced methods generates detailed structural and chemical 'fingerprint signatures' as nuclear safeguards.

Hydrolysis products and oxides are being fabricated and characterised to establish a library of reference signatures and improve analytical methodologies for materials containing uranium or plutonium. These materials are used to develop and validate techniques that determine crystal structure, microstructure, elemental composition, oxidation state, isotopic content, and other physical properties. The resulting datasets enhance Australia's ability to identify and interpret material 'fingerprints' and strengthen national expertise in nuclear safeguards and nuclear forensics.

THE IMPACT

A suite of uranium-bearing nuclear materials has been synthesised and characterised as standards for nuclear forensics and safeguards. Advanced synchrotron techniques have been developed and implemented to generate unique structural and spectroscopic signatures that improve the identification and attribution of nuclear materials.

The research has produced a sustained record of high-impact scientific publications and strengthened Australia's technical expertise in the characterisation of nuclear materials. Importantly, the project has also contributed to workforce development by providing specialised training for three early-career researchers and three PhD students, helping to build the next generation of Australian nuclear scientists.



Australian Research Priority or Futures Made in Australia Framework

- Building a secure and resilient nation
- Transitioning to a net zero future

ANSTO strategic priority

- Australia's source of nuclear expertise, advice and services
- Lead the development of a nuclear capable workforce

ANSTO capability/instrument

Synthesis and characterization of actinide materials

Australian Synchrotron

MX1 and MX2

Macromolecular and Microfocus Crystallography

MEX1 and MEX2

Medium Energy X-ray Absorption Spectroscopy

PD

Powder Diffraction

Australian Center of Neutron Scattering

WOMBAT

High-Intensity Diffractometer

ECHIDNA

High-Resolution Powder Diffractometer

Collaborators/clients

- The University of Sydney
- University of New South Wales
- Jülich Institute, Germany
- Australian Non-Proliferation Office (ASNO)

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Image:
AI generated image of a subsea oil and gas pipeline. (Google Gemini)

Ensuring safe operation of nuclear engineering systems

THE CHALLENGE

Nuclear reactor pressure vessels must remain safe over several decades of operation. Neutron irradiation in a reactor gradually reduces material toughness, while repeated start-up and shut-down cycles impose fatigue loading. Together, these mechanisms can initiate cracks or accelerate existing flaws, particularly in regions close to the reactor core and during lower-temperature variations. Assessing either mechanism in isolation can underestimate risk. A reliable lifetime assessment must quantify how irradiation embrittlement and cyclic loading interact, identify the most vulnerable locations and determine whether flaws will remain stable or grow to failure.

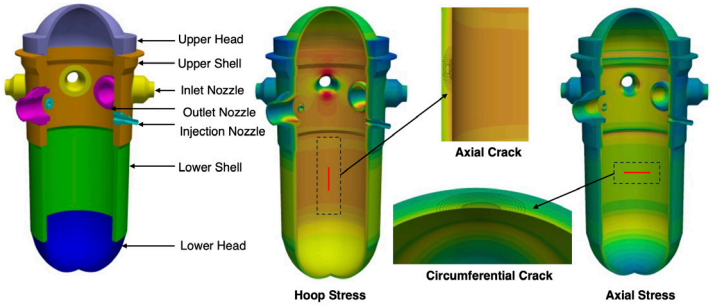
THE SOLUTION

ANSTO and Idaho National Laboratory (USA) have developed an integrated computational fracture mechanics assessment for the Westinghouse AP1000 reactor pressure vessel. Models simulated all normal operating events, including heat-up, cool-down and pressure changes. The method combined transient stresses, fatigue crack growth and irradiation-dependent fracture toughness to evaluate a range of representative flaws at critical vessel locations.

By tracking each flaw over successive operating cycles, the analysis distinguished stable, manageable crack growth from conditions approaching structural failure. It also isolated the effects of flaw orientation, location, depth, temperature and neutron fluence. This provided a consistent basis for identifying the most vulnerable vessel regions and the mechanisms that govern long-term integrity.

THE IMPACT

The results showed that vessel regions closest to the reactor core are most sensitive to irradiation embrittlement, while lower-temperature conditions can further reduce fracture resistance. This evidence-based method enables operators to prioritise inspections, evaluate life-extension decisions and manage component integrity throughout service. Demonstrating the approach on the widely deployed AP1000 reactor system strengthens ANSTO's capability to support Australia's nuclear engineering systems and provide independent structural-integrity advice internationally.



Australian Research Priority or Futures Made in Australia Framework

- Economic Resilience and Security Stream

ANSTO strategic priority

- Deliver on Australia's priorities for the benefit of people, industry and the environment
- Expert nuclear advice to government and industry

ANSTO capability/instrument

High-performance computing
Finite element analysis
Fracture mechanics
Computational structural integrity assessment

Collaborators/clients

- Idaho National Laboratory, USA

ANSTO contributors

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- Dr Benjamin W. Spencer

Paper DOI

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Image:
Prediction of operational stresses in the AP1000 reactor pressure vessel and predicted crack growth.

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Ensuring seafood safety in a nuclear world

THE CHALLENGE

Ensuring seafood integrity is especially important in Asia and Oceania where seafood is a dietary staple with more than 50 new nuclear power plants currently under construction. Low levels of radionuclides are found more often in seafood than in other foods, making seafood a focus of public concern during routine operation of industry or following nuclear events such as the Fukushima accident. However, important questions remain unanswered including:

Which radionuclides—naturally occurring or manmade—contribute most to typical radionuclide exposure from seafood?

Are such exposures increasing or decreasing over time?

These questions have been difficult to answer because the necessary data were not available in previous years and because new analysis tools are needed for the large datasets now coming online.

THE SOLUTION

ANSTO joined with world experts to expand the leading database for radionuclides in the marine environment. More than 20,000 new data entries were added to the Marine Radioactivity Information System (MARIS) administered by the Monaco Laboratories of the International Atomic Energy Agency (IAEA). This massive expansion enabled new approaches that had not previously been possible.

The researchers then used a custom Monte Carlo analysis to evaluate the contribution of 16 key radionuclides across six major seafood categories worldwide. The data from Australia, China, Japan and other countries was sorted and assessed individually to estimate seafood safety in different regions.

The Marine Radioactivity Information System (MARIS) now contains widespread radionuclide data across the world's oceans.

THE IMPACT

The project gives Australian and world researchers new tools to conduct their own studies. For example, assessing the impacts from coastal nuclear power plants is important for ensuring seafood integrity across the entire surrounding region because the ocean currents do not stop at national borders. ANSTO environmental scientists are providing new resources to improve these assessments, promote consistency and make it easier to compare and share safety information between countries.

The research highlights the importance of understanding both naturally occurring and manmade radionuclides in seafood and provides new tools and data to bolster the monitoring of Australian seafood carried out by ANSTO and ARPANSA.



Australian Research Priority or Futures Made in Australia Framework

- Protecting and restoring Australia's environment
- Supporting healthy and thriving communities

ANSTO strategic priority

- Australia's source of nuclear expertise, advice and services

ANSTO capability/instrument

Radiological dose and dose modelling

Collaborators/clients

- Australian Radiation Protection and Nuclear Safety Agency (ARPANSA)
- International Atomic Energy Agency (IAEA)
- Japan Atomic Energy Agency (JAEA)
- Norwegian Radiation and Nuclear Safety Authority (DSA)
- French Authority for Nuclear Safety and Radiation Protection (ANSR)

ANSTO contributors

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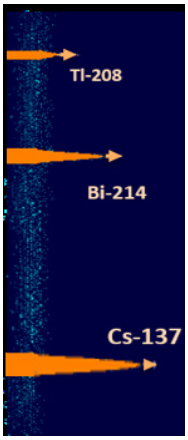

Image:
Gamma spectroscopy (above) is just one of several methods required to measure the very low levels of naturally-occurring and man-made radionuclides in seafood.

From printed defects to service-ready performance using hot isostatic pressing (HIP)

THE CHALLENGE

High-temperature systems are used in the food industry to process organic waste streams and recover energy. Injector nozzles operating within these systems are exposed to severe thermal, corrosive and erosive conditions. Nickel alloys, such as Hastelloy X, are selected for these systems because of their excellent high-temperature strength, oxidation resistance and corrosion resistance. The conventional manufacturing process relies on specialised casting followed by machining, which is typically sourced internationally. To produce these items within Australia, an alternative processing pathway using additive manufacturing was identified as feasible whilst maintaining the required quality, structural integrity and in-service performance equivalent to that of traditionally manufactured items.

THE SOLUTION

Laser Powder Bed Fusion (LPBF) and Hot Isostatic Pressing (HIP) were selected to manufacture Hastelloy X injector nozzles. These methods are particularly well suited to low-volume, high-value bespoke components with the distinct advantage of producing near net shape parts that require minimal final machining. LPBF suited the complex geometry in the manufacturing, while HIP was applied to improve material density, integrity and performance. Feasibility studies on small-scale test pieces initially confirmed an improved performance. A scale-up to the final component size (H: 400 mm, D: 105 mm) and geometry followed testing. ANSTO has a unique Australian capability to HIP industrial-scale parts. The HIP processing eliminated pores, cracks and other defects. It produced a material with greater than 99% density according to calculations, a 50% increase in elongation and superior tensile properties regardless of build orientation (often a challenge with additively manufactured parts), without measurable distortion. Analysis showed that HIP processing transformed the highly directional as-printed microstructure into a more homogeneous structure. This transformation explained the improved ductility and uniform mechanical behaviour.

THE IMPACT

LPBF and HIP were subsequently demonstrated at scale in 42 parts over a series of HIP runs at temperatures and pressures up to 1200°C and 150 MPa. This work demonstrated that combining additive manufacturing with scalable thermal treatment enables the reliable production of complex components in a sovereign Australian supply chain while meeting the rigorous performance requirements of high-temperature applications. The finished products met the required materials performance criteria and have subsequently been deployed in the commissioning and operation of the high-temperature application.

Australian Research Priority or Futures Made in Australia Framework

- Futures Made in Australia — Economic Resilience and Security Stream

ANSTO strategic priority

- Deliver on Australia's priorities for the benefit of people, industry and the environment

ANSTO capability/instrument

Hot isostatic pressing
Advanced materials characterisation
Performance qualification

Collaborators/clients

- Australian Additive Engineering Pty Ltd
- Plater International Consulting Pty Ltd

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- Ronny Calderon Vicencio
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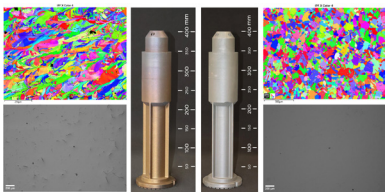

Image:
Electron backscatter diffraction maps, optical micrographs and photographs of LPBF Hastelloy X parts: (a) pre-HIP; (b) post-HIP.

Immobilising radioactive caesium in nuclear wastes

THE CHALLENGE

The sustainable production of molybdenum-99 (Mo-99) for nuclear medicine requires effective treatment and disposal pathways for the associated radioactive waste streams generated during processing. One treatment option under investigation uses an ion exchange material, IONSIV®, to remove radioactive caesium and reduce activity in the liquid waste stream. However, the resultant material becomes a secondary form of radioactive waste that requires long-term management. Similar wastes are generated internationally from nuclear waste treatment and contaminated water remediation programs. ANSTO wanted a practical waste treatment solution capable of minimising waste volume, while accommodating variations in waste chemistry to provide a safe pathway for long-term disposal.

THE SOLUTION

ANSTO developed a novel glass-ceramic wasteform using ANSTO Synroc® technology to immobilise caesium in the exchange process. A systematic evaluation of ceramic, glass and glass-ceramic formulations identified a tailored pollucite (a zeolite mineral) glass-ceramic as the preferred solution. It could achieve waste loadings of up to 70–80 wt.% while selectively incorporating caesium into a highly durable crystalline material. The work further expanded the application of ANSTO Synroc® technology beyond traditional waste streams. The wasteform was designed to remain effective despite variations in caesium loading and was tailored for hot isostatic pressing (HIP), a core component of the ANSTO Synroc® technology. The approach produced dense, low-porosity materials, while minimising volatile gases and secondary waste generation during processing. Chemical durability testing demonstrated a superior performance compared with alternative ceramic and glass wasteforms.

THE IMPACT

This work provides ANSTO with a feasible treatment and disposal pathway for secondary wastes containing caesium arising from Mo-99 production. The optimised pollucite glass-ceramic combines high waste loading, reduced disposal volume, excellent chemical durability and compatibility with HIP processing. It extends the application of ANSTO Synroc® technology to challenging secondary waste streams and provides a potential solution for caesium-loaded IONSIV® wastes generated internationally through nuclear waste treatment and contaminated water remediation programs. The research has generated multiple peer-reviewed publications.



Image:
HIPed glass and glass-ceramic wasteforms developed using Synroc Technology for immobilising Cs-loaded IONSIV® ion exchange waste showing ~60% volume reduction with increasing waste loading to 70% in the glass-ceramic wasteform.

ANSTO strategic priority

- Sustainable Waste Management
- Development of Synroc Technology

ANSTO capability/instrument

Advanced Materials Characterisation
ANSTO Synroc® Technology
Hot Isostatic Pressing (HIP)

Collaborators/clients

- University of New South Wales

ANSTO contributors

- Synroc Team
- Minerals
- Waste Management Services
- Nuclear Medicine

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International benchmarking of important technique in nuclear forensics

THE CHALLENGE

Particle morphology, using the shape, size, and structure of tiny particles to identify or understand a material, is an emerging signature within nuclear forensic science. Microscopic details present in the shape and size of particles found throughout the nuclear fuel cycle may convey historical information about processing. International research investigating particle morphology uses several different analytical techniques and data processing methods to produce both qualitative and quantitative data. For particle morphology to be applied by a nuclear forensic laboratory in help provenance of nuclear or other radioactive material found out of regulatory control, further research is required to identify, evaluate and validate standardised quantitative analysis method.

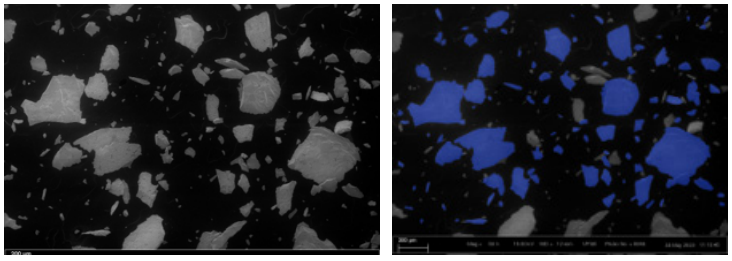
THE SOLUTION

An international interlaboratory nuclear forensic exercise, coordinated by the Canadian Nuclear Laboratories, collected scanning electron microscopy images of five different uranium powders found throughout the nuclear fuel cycle and distributed them to ANSTO and six other international nuclear forensic laboratories. Exercise participants analysed particle morphology characterisation in their laboratories using specialised image analysis software to extract quantitative data for several different microscopic particle shape and size attributes.

Results were compiled to compare this data from the different powders as well as between the different nuclear forensic laboratories. This provided a benchmark of the current nuclear forensic capability for particle morphological analysis. Despite the different approaches used, consensus on the distinct physical attributes of each powder analysed was reached. ANSTO was one of only two nuclear forensic laboratories that were able to differentiate between all five uranium powders.

THE IMPACT

This interlaboratory exercise was a valuable opportunity to work alongside international nuclear forensics experts. The current capability of particle morphology was evaluated; best practices, as well as the identification of areas of future research, were determined. This, together with the establishment of a working group of practitioners to further this area of research, provides a strong foundation to uplift particle morphology as a reliable signature for nuclear forensics. ANSTO's participation in interlaboratory exercises such as these reinforces its standing as a leading international laboratory committed to the technical advancement of nuclear forensic science.



Australian Research Priority or Futures Made in Australia Framework

- Building a secure and resilient nation

ANSTO strategic priority

- Be Australia's source of nuclear expertise, advice and services to governments, academia, industry, and community

ANSTO capability/instrument

Nuclear Forensics

Collaborators/clients

- Canadian Nuclear Laboratories
- Joint Research Centre Karlsruhe, EU Commission
- Lawrence Livermore National Laboratory, USA
- Los Alamos National Laboratory, USA
- DSO National Laboratories, Singapore
- Japan Atomic Energy Agency
- University of Utah, USA

ANSTO contributors

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- Emma Young
- Corey Pont

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Image:
Scanning electron microscopy image of a uranium oxide powder (left) and the same image analysed using software at ANSTO to extract quantitative data from each particle identified (blue) (right).

New, stable materials to treat radioactive wastes

THE CHALLENGE

Treatment of radioactive wastes requires processes that are not only effective but can also function in highly acidic and radioactive environments.

Radioactive waste treatment includes techniques to separate out targeted radionuclides, such as the long-lived, radioactive actinide elements, uranium, plutonium, neptunium, americium and curium. For example, used nuclear fuel is an important radioactive waste from the nuclear industry that is typically treated by solvent extraction. However, both the organic molecules and solvents used in solvent extraction are generally susceptible to radiation damage. Once damaged, they become a secondary source of waste requiring further management.

THE SOLUTION

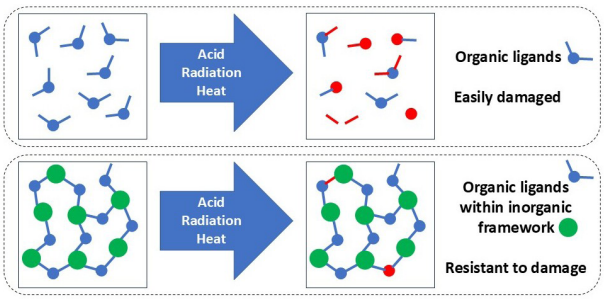
Materials are being developed at ANSTO for the separation of the actinide elements from radioactive wastes without organic solvents. Commercially available adsorbent materials are typically polymer-based resins with low stability or inorganic materials with poor separation selectivity. Therefore, the team has developed hybrid materials combining the chemical stability of an inorganic framework with the selectivity of organic molecules. These zirconium and titanium phosphonate hybrid materials have proven highly effective for actinide separations and have recently been demonstrated to also have excellent acid tolerance and stability in radioactive environments.

A detailed characterisation of the phosphonate materials after exposure to acid or radiation using nuclear and synchrotron techniques revealed the strength of the specific bonds was responsible for their enhanced stability. This mechanistic insight will enable design of even more stable materials in future.

THE IMPACT

Enhancing the stability of these materials means they can be used in harsh environments, such as those present in radioactive wastes. They can also be re-used multiple times before degrading, which improves the sustainability and cost-effectiveness of the waste treatment technology. Radioactive wastes requiring treatment are also found across the mining industry and contaminated environments. These advanced materials demonstrate the potential to reduce hazards to people and the environment and improve public perception across all nuclear technologies.

In 2025–2026, two honours students and one PhD candidate have undertaken projects developing stable materials to treat radioactive wastes.



Australian Research Priority or Futures Made in Australia Framework

- Transitioning to a net zero future
- Building a secure and resilient nation

ANSTO strategic priority

- Australia's source of nuclear expertise, advice and services

ANSTO capability/instrument

Materials Fabrication Bay and Active Characterisation
Inactive Chemistry and Characterisation
Electron Microscopy

Australian Synchrotron
SXR
Soft X-ray spectroscopy
MEX1 – MEX2
Medium Energy X-ray absorption spectroscopy

National Deuteration Facility
Deuteration
NMR, synthesis

Elemental analysis

Collaborators/clients

- University of New South Wales
- The French Alternative Energies and Atomic Energy Commission (CEA), France
- Swinburne University of Technology
- University of Wollongong

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- Dr Daniel Oldfield
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- Annastasia Bedford

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Image:
Metal phosphonate materials demonstrate enhanced stability towards acid, radiation and temperature, relative to organic phosphonates alone

Nuclear forensics supports Australian Border Force and historic ruling

THE CHALLENGE

ANSTO, home to Australia's sovereign nuclear forensic science capability, was requested by the Australian Border Force (ABF) in August 2023 to forensically examine 56 items seized during the execution of multiple warrants at a person-of-interest's (POI) residence. ANSTO was asked to determine whether the items contained nuclear and/or radioactive materials, whose possession or importation into Australia may constitute several different offences under Commonwealth legislation. Although significant numbers of items posed various complex chemical and/or radiological hazards, ANSTO maintained evidentiary integrity: that is, that evidence has been preserved, handled and documented in a way that remains complete, accurate and completely unaltered from the moment of collection until it is presented in court to deliver robust forensics conclusions in a safe and compliant manner.

THE SOLUTION

ANSTO called on its operational capability comprising subject matter experts from ANSTO with expertise in forensics, gamma spectroscopy, X-ray fluorescence spectroscopy, handling of unsealed radioactive materials and chemical and radiation safety. Together, this interdisciplinary team safely examined all 56 items, incorporating key forensic considerations such as thorough documentation and chain of custody to ensure findings were suitable for legal proceedings.

Nine of the seized items contained nuclear material and seven items contained radioactive material. The remaining 40 items were not found to contain detectable radioactive materials. An expert witness report was provided to the ABF in September 2023 for inclusion in their brief of evidence. ANSTO continued to support the ABF, the Australian Safeguards and Non-Proliferation Office and Commonwealth legal departments during the prosecution through consultation and additional expert witness statements.

THE IMPACT

ANSTO provided Australian law enforcement a one-of-a-kind capability to examine nuclear and other radioactive material out of regulatory control. This investigation resulted in the first successful prosecution under the **Nuclear Non-Proliferation (Safeguards) Act 1987** and the first offences relating to radioactive substances under the **Customs Act 1901**. Through its investigation, ANSTO identified the 16 items with radioactive or nuclear materials present, which was critical to the prosecution. It demonstrated the critical role of nuclear forensics in national nuclear security capabilities. It reaffirmed ANSTO's reputation as a trusted organisation for expert advice and support in nuclear forensics and nuclear science.



Image:
Nuclear forensic examination of seized items at ANSTO facilities.

Australian Research Priority or Futures Made in Australia Framework

- Building a secure and resilient nation

ANSTO strategic priority

- Be Australia's source of nuclear expertise, advice and services

ANSTO capability/instrument

Nuclear Forensics

Collaborators/clients

- Australian Border Force
- Australian Safeguards and Non-Proliferation Office

ANSTO contributors

- Nuclear Forensics
- Detection and Imaging
- High Reliability
- Nuclear Materials Research Technology Group
- Radionuclide Metrology
- Waste Characterisation
- Radioanalytical Chemistry
- Low Level Radioactivity Group

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Radiation safety assessments at legacy nuclear site

THE CHALLENGE

In the years following the nuclear weapons tests by the British at the Montebello Islands in Western Australia, the monitoring of hazards relied on detecting gamma radiation, the same type of radiation used in X-rays. However, much of this distinct gamma signal from the blast has now decayed, and monitoring increasingly depends on detecting alpha radiation, which is far more difficult to measure. Despite this challenge, alpha measurements are essential for ensuring the safety of the site because the nuclear detonations were fuelled by plutonium, a long-lived contaminant that will remain in the environment for thousands of years.

THE SOLUTION

ANSTO uses a smart combination of three techniques to measure plutonium's alpha radiation in a wide variety of Montebello sample types:

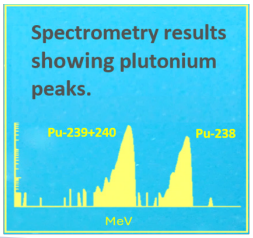
- Low-energy gamma spectroscopy measures specific radioactive elements that are linked to plutonium and can rapidly analyse large numbers of samples.
- Alpha Spectrometry measures plutonium directly and relates it to other important radioactive elements, providing a broader understanding of contamination.
- Accelerator Mass Spectrometry provides the most sensitive measurements—detecting plutonium at extremely low levels in high-value samples, including tiny specimens such as a non-lethal skin biopsy from a sea turtle.

By combining the strengths of all three techniques, environment scientists at ANSTO accurately mapped the plutonium levels across the islands, tested historic objects that island visitors may be tempted to handle and measured the amounts of plutonium taken up by endangered species.

THE IMPACT

ANSTO's work improves safety to site visitors, the staff of the WA government and site managers. Because some areas of the island still have elevated plutonium levels, active health and safety measures and access restrictions remain necessary now and into the future. Without ANSTO's alpha detection capabilities, site managers and the public would have little way to identify these hazards.

ANSTO data also helped assess risks to the wildlife of the protected marine park. Measurements found that the radionuclides at the sea turtle nesting beaches pose only low risk to the adult turtles and their developing eggs. However, some of the mammals living further inland are more exposed to radionuclides because they interact daily with contaminated soils. ANSTO is working with site managers to better understand these risks and guide future management.





Australian Research Priority or Futures Made in Australia Framework

- Protecting and restoring Australia's environment
- Supporting healthy and thriving communities

ANSTO strategic priority

- Australia's source of nuclear expertise, advice and services

ANSTO capability/instrument

Centre for Accelerator Science
Accelerator mass spectrometry
Alpha and gamma spectrometry
Dose assessment

Collaborators/clients

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- Edith Cowan University
- Australian National University

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- Esrat Jahan
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- Adella Silitonga
- Isabella Naletilic
- Julia Martinello
- Nick Howell

Paper DOI

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Image:
Site Manager Tim Hunt collecting a sample from the propeller remains of the HMS Plym, a ship destroyed as part of the first nuclear test at Montebello Islands. Photo credit: Tim Hunt

Research to support IAEA nuclear safeguards requirements

THE CHALLENGE

International nuclear safeguards verify that nuclear facilities and materials are not misused or diverted from peaceful uses. Verification activities rely on the accurate detection, characterisation and attribution of trace nuclear materials through a program of environmental swipe analysis. Considering the constraints in sensitivity limits and background contamination from sampling, this research improves detection limits and develops new analysis techniques.

Overcoming analytical limitations can enhance confidence in nuclear safeguards interpretation, such as those encountered in environmental swipe samples. Addressing these challenges through a collaborative program of advancing measurement sensitivity, sample preparation and analytical capability was the focus of this project. In Australia, the technical expertise and speciality instrumentation that can undertake this work is limited.

THE SOLUTION

Novel sample preparation methods and techniques were developed for particle recovery and non-destructive analysis. This approach improved sampling throughput and enabled effective characterisation. Statistical analysis confirmed that factors such as image magnification influenced morphology data on the concentration of uranium ore. This confirmation assists data interpretation.

In parallel, new protocols for a highly precise determination of key isotopic information in nuclear material demonstrated a performance consistent with International Atomic Energy Agency (IAEA) Network of Analytical Laboratories (NWAL) requirements. Further analytical methods were developed for the age dating of nuclear materials using the actinides collected on environmental swipe samples leveraging the sensitivity of ANSTO's Vega Accelerator.

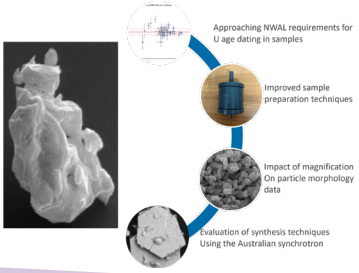
Knowledge gaps were reduced with applications of synchrotron techniques for the characterisation of materials containing actinides relevant to nuclear safeguards. Analytical frameworks were established to provide high-precision data, in support of robust analytical signatures that are strongly aligned with safeguarding objectives.

THE IMPACT

Together, these results provide a valued contribution to developments in technical measures for nuclear safeguards by improving analytical sensitivity, enhancing particle recovery and strengthening current techniques and tools.

This work strengthened science and technology exchange between ANSTO, ASNO, and Australian universities, and increased the hands-on experience of researchers. The newly established mechanisms for cooperation will benefit the future of Australia's nuclear workforce.

This work was funded by the Australian Safeguards and Non-proliferation Office (ASNO) and informed by an International Atomic Energy Agency (IAEA) focus on technical capabilities for nuclear material and environmental sample analysis.



Australian Research Priority or Futures Made in Australia Framework

- Building a secure and resilient nation

ANSTO strategic priority

- Australia's source of nuclear expertise, advice and services
- Lead the development of a nuclear capable workforce

ANSTO capability/instrument

Centre for Accelerator Science
VEGA 1MV Accelerator
Accelerator Mass spectrometry

Australian Synchrotron
MX1 and MX2
Macromolecular and microfocus crystallography
MEX1 and MEX2
Medium X-ray absorption spectroscopy
PD
Powder diffraction

Collaborators/clients

- Centre for Accelerator Science
- Nuclear Materials Research and Technology
- Nuclear Forensics
- Australian Safeguards and Non-Proliferation Office
- Curtin University
- University of Western Australia

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- Alain Moriana
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Image:
Nuclear materials samples can have multiple approaches to investigations to determine important information related to safeguards.

Responsible management of an historic waste site

THE CHALLENGE

The Little Forest Legacy Site (LFLS) at ANSTO was used for the disposal of low-level radioactive wastes in the 1960s. As the site contains radioactive and non-radioactive contaminants, the potential environmental impacts need to be assessed, managed and minimised. The specific challenges at LFLS included incomplete knowledge of the trench contents, the complex interactions involving numerous contaminants and the need to understand the environmental processes which may cause the contamination to move through the environment.

THE SOLUTION

Scientific studies showed that whilst the releases of contaminants were within acceptable levels, an ongoing concern at the site was the possible mobilisation of contaminants resulting from rainwater entering the historic waste trenches. The research undertaken at LFLS has informed the selection and installation of the preferred management option to address the entry of water. Consequently, a multi-layer engineered cover was installed in 2024 to minimise the long-term environmental impact.

THE IMPACT

The scientific work has Increased community and stakeholder confidence that ANSTO is responsibly managing the site.

The project has enabled and strengthened external linkages, including those with Australian and overseas universities, and with the International Atomic Energy Agency (IAEA). The LFLS featured in the recent IAEA report: IAEA NW-G-3.3: *Environmental Remediation and Management of Trenches Containing Historic Radioactive Wastes (2025).*

The work showcased world-leading ANSTO expertise, including Accelerator Mass Spectrometry (AMS), isotopic techniques, and synchrotron techniques in environmental applications.

It has generated significant knowledge about the mobility of radionuclides in the environment, which is of value to the international community dealing with numerous similar sites worldwide.



Australian Research Priority or Futures Made in Australia Framework

- Protecting and restoring Australia's environment

ANSTO strategic priority

- Be Australia's source of nuclear expertise, advice and services to governments, academia, industry, and community

ANSTO capability/instrument

Radioanalytical chemistry
Accelerator techniques including accelerator mass spectrometry
Environmental monitoring
Synchrotron techniques

Collaborators/clients

- University of New South Wales Environmental Engineering

ANSTO contributors

- Nuclear Stewardship
- Environmental Research and Technology Group
- Environmental Monitoring
- Radioanalytical Chemistry
- Centre for Accelerator Science
- Waste Management
- Engineering
- Australian Synchrotron

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Image:
Multi-layer cover during installation at Little Forest Legacy Site. The geomembrane that can be seen in this photo is part of a multi-layer barrier and has been covered with layers of earth and vegetation.

Reusable targets for the production of an important medical radioisotope

THE CHALLENGE

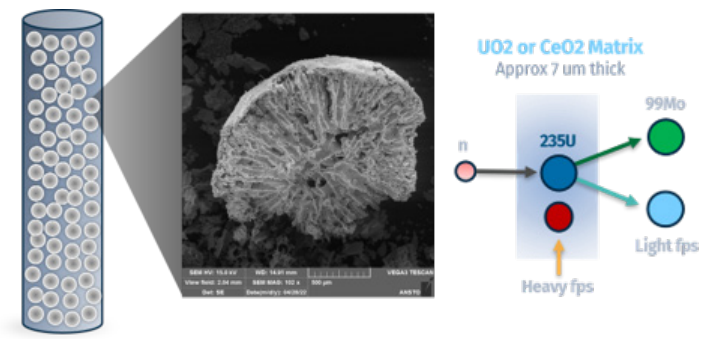
Can we make Molybdenum-99 (mo-99), an important medical radioisotope, in a more sustainable way? Mo-99 decays to technetium-99m (Tc-99m), the most commonly used nuclear medicine to diagnose heart disease and other illnesses. Part of ANSTO's core mission is to produce this important product, which is distributed safely in Gentech® Generators nationally and internationally. However, the current production process is based on a technology developed decades ago. The current multi-step process of dissolving targets, the source materials, can lead to a low yield and creates undesirable fission products as waste. The more economical production of Mo-99 with less uranium-235 (U-235) in targets and the production of less waste would have a great benefit to Australia.

THE SOLUTION

A team from ANSTO and the University of Wollongong has capitalised on existing knowledge and Mo-99 production, nuclear fuel and the fission of U-235 to develop improved targets. Previous work, which gained a provisional patent, focused on modelling to determine yields from a porous reusable target. The next stage is under way with proof-of-concept experiments involving the fabrication and irradiation of simulated targets. These targets have been designed using a fraction of U-235 (1–2%) compared to current low enriched uranium targets (20%). They eject Mo-99 when the U-235 undergoes fission, removing the need to dissolve the target and allowing Mo-99 to be flushed out. Reuse consumes all the U-235. In parallel, the team is working on applying the technology to accelerator-based systems that could be implemented on a much smaller scale than current reactor-based systems.

THE IMPACT

This project not only protects Australia's sovereign capability to produce Mo-99 but future-proofs it against competing technologies in the worldwide marketplace. ANSTO will be able to produce Mo-99 more economically, while producing less waste. It may be possible to also make the targets at the Lucas Heights facility and reduce the cost of Mo-99 production significantly.



Australian Research Priority or Futures Made in Australia Framework

- Supporting healthy and thriving communities
- Building a secure and resilient nation

ANSTO strategic priority

- Deliver on Australia's priorities for the benefit of people, industry and the environment
- Improve the health of Australians by supporting access to current and future nuclear technologies

ANSTO capability/instrument

MCN-P

Open MC running on ANSTO computer hardware

OPAL irradiation facility

Wet chemistry labs

Active fabrication and characterisation labs

Microscopy facility

Australian Centre for Accelerator Science.

Collaborators/clients

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ANSTO contributors

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- Robert Raposio
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- Dr Timothy Ablott
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- Attila Stopic
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Paper DOI

doi.org/10.3390/jne3040017

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Image:
Irradiation of a column of porous spheres.

Simulations ensure the structural integrity of engineering components

THE CHALLENGE

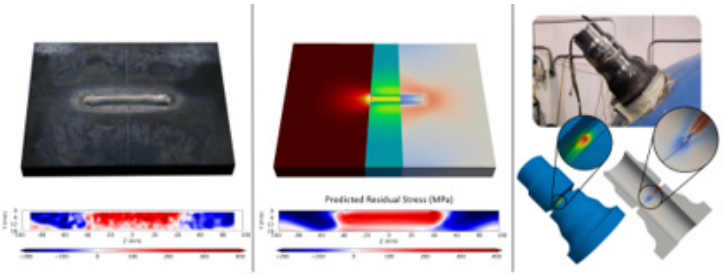
Welding remains the primary manufacturing process in industy, while additive manufacturing is emerging as a key technology for rapid repair and prototyping. Both subject materials to intense heating and cooling cycles, leading to macroscopic distortions, residual stresses and potentially compromised microstructure. Residual stresses, hidden within the material, can add to operational service stresses, potentially pushing components beyond their safe design limits. Distortions become particularly important when producing or repairing large, complex engineering components as dimensional inaccuracies can be costly to remediate. Predicting these effects before a component enters service is essential, yet measuring them experimentally is difficult, expensive and time-consuming.

THE SOLUTION

In collaboration with Argonne National Laboratory and Idaho National Laboratory, ANSTO has developed advanced simulations capable of predicting residual stresses, distortions and post-weld microstructure in multi-pass weldments, as well as additively manufactured components. These models capture the complex interplay between heat input, solid-state phase transformations and mechanical response during the manufacturing process. The modelling methodologies were validated against neutron and X-ray diffraction residual stress measurements. Measurements demonstrated that the models accurately capture how process parameters, such as welding sequence, interpass temperature and deposition strategy, influence the resulting stress state, microstructure, and distortion. The validated simulation framework was applied to multi-pass weldments that are representative of those found in nuclear engineering components. Critical insights into the magnitude and distribution of welding-induced residual stresses are essential for fitness-for-service assessment and safe long-term operation.

THE IMPACT

This work has provided critical insight into the magnitude and distribution of residual stresses in nuclear engineering components, directly supporting the safe and reliable operation of nuclear engineering systems. Beyond the nuclear sector, the simulation tools have been applied in collaboration with BAE Systems to understand and minimise welding-induced distortions in large welded ship panels. The results reduce costly rework and improve manufacturing efficiency. The same numerical framework has been extended to support additive manufacturing as a rapid repair technology for high-value structural components in the aerospace sector. Advanced computational tools can deliver real-world industrial outcomes.



Australian Research Priority or Futures Made in Australia Framework

- Futures Made in Australia — Economic Resilience and Security Stream

ANSTO strategic priority

- Deliver on Australia's priorities for the benefit of people, industry and the environment
- Expert nuclear advice to government and industry

ANSTO capability/instrument

High-performance computing
Finite element analysis

Australian Centre for Neutron Scattering
KOWARI
Strain/stress diffractometer

Collaborators/clients

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Paper DOI

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Image:
Predicted residual stress field in multi-pass welds for (i) the benchmark specimen and (ii) the safety relief valve nozzle.

Supporting non-proliferation and the security of nuclear facilities

THE CHALLENGE

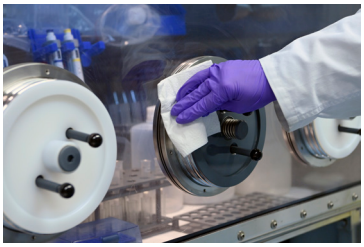
When international inspectors take samples at a nuclear facility, the first task is to identify what material is present. However, the more difficult question is when the material was made. Inspectors wipe surfaces with cotton swabs and send the dust for analysis, which reveals the type of nuclear material but not whether it comes from recent operations or from past activities. That difference can determine whether a country is honouring its commitment to the Nuclear Non-Proliferation Treaty. The International Atomic Energy Agency (IAEA) has formally identified the age-dating of uranium and plutonium in these tiny environmental samples as a top priority.

THE SOLUTION

ANSTO developed a method that reads a chronology from the material itself. A form of the radioactive element plutonium steadily decays into a form of americium, which is also radioactive. The two rates of decay act as a clock that starts when the plutonium was made or last purified. Using ultra-sensitive accelerator mass spectrometry, the team took measurements in samples of a few femtograms. Each sample sent by inspectors is only a quadrillionth of a gram. The americium is detected at quantities approaching a billionth of a billionth of a gram. To prove the method, the team dated plutonium traces in soils and sediments from known sources, including fallout from weapons tests and past accidents at nuclear facilities. In every case, the measured ages matched the known production history, confirming the technique gives reliable ages from real-world samples.

THE IMPACT

Inspectors can now answer the 'when' question from collected samples and distinguish legacy contamination from evidence of recent activity at far lower quantities than any other method. ANSTO's Centre for Accelerator Science is a member of the IAEA's Network of Analytical Laboratories, a select group of facilities that analyse inspection samples for the agency. This capability and participation in the network directly supports Australia's contribution to international nuclear verification, a system that gives the world confidence that countries are honouring their obligations under the **Nuclear Non-Proliferation Treaty.**





Australian Research Priority or Futures Made in Australia Framework

- Building a secure and resilient nation

ANSTO strategic priority

- Australia's source of nuclear expertise, advice and services to governments, academia, industry and the community

ANSTO capability/instrument

Centre for Accelerator Science
1MV VEGA Accelerator
Actinide accelerator mass spectrometry

Collaborators/clients

- Australian Safeguards and Non-proliferation Office (ASNO)
- IAEA

ANSTO contributors

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- Andrea Johansen
- Dr Mathew Johansen
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- Carisa O'Connor

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Image:
(A) An International Atomic Energy Agency inspector collects swipe samples during an inspection (Photo credit: IAEA Imagebank); (B) ANSTO's VEGA accelerator, where plutonium in such samples is age-dated.



Use of research infrastructure and services

The use of research infrastructure and services delivers benefits to Australia

ANSTO operates nationally significant research infrastructure that provides Australia with unique, world-class scientific capabilities. Supported through the Australian Government's National Collaborative Research Infrastructure Strategy (NCRIS), ANSTO enables thousands of researchers, industry partners and government agencies each year to access facilities including the Australian Synchrotron, Australian Centre for Neutron Scattering, Centre for Accelerator Science and National Deuteration Facility.

These facilities support research and innovation that address national priorities in health, environmental sustainability, Indigenous knowledge systems, critical technologies, resources, security and resilience. They also strengthen Australia's sovereign scientific capability and develop the specialist workforce required for future nuclear, engineering and technology sectors.

By supporting the translation of cutting-edge science into practical outcomes, ANSTO's infrastructure delivers benefits for Australians, supports domestic industry, and contributes to national productivity, competitiveness and economic prosperity.

Acid bake technology development for enhanced rare earth processing

THE CHALLENGE

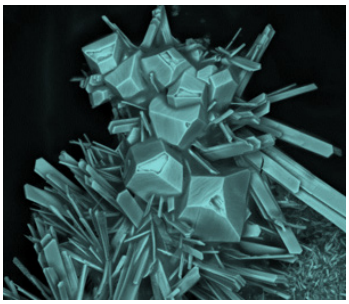
Rare earth elements are used in a myriad of modern technologies that support renewable energy, industry and defence. The majority of the world's rare earth elements are processed using the sulfuric acid 'bake' process, which cracks the host mineral, releasing the rare earth elements prior to subsequent purification and separation. Although this is an old process, there has been a notable lack of understanding of the fundamental chemistry involved. Differing feedstocks were known to give vastly different performance through the bake; however, little was known about the underpinning mechanisms at play.

THE SOLUTION

Given the importance of the acid bake process to the global rare earth industry, ANSTO's Minerals team undertook in-depth fundamental studies of the process. This research involved breaking down the role of each individual mineral component through detailed, systematic studies that leveraged some of ANSTO's unique characterisation capabilities. One of the major findings was that various types of silicates (natural minerals), when used as additives in the bake process, provide a significant enhancement in rare earth extraction across a wide range of process conditions. This finding formed the basis of a patented rare earth processing technology.

THE IMPACT

The bake process patent has gained commercial interest with testing undertaken for various potential industry partners. In addition, a broader fundamental understanding of the intrinsic chemistry involved in the acid bake process has helped position ANSTO as a recognised global technology leader in rare earth processing. In Australia, ANSTO has been involved in development and/or operations improvement for all major Australian rare earth bake projects. ANSTO patent enhances performance of primary RE mineral cracking process used globally.







Australian Research Priority or Futures Made in Australia Framework

- Building a secure and resilient nation
- Transition to a net zero future
- Growing Australia's sovereign capability in critical minerals processing

ANSTO strategic priority

- Deliver on Australia's priorities for the benefit of people, industry and the environment

ANSTO capability/instrument

in-situ XRD, TGA-DTA
Minerals Pilot Plant
Minerals QEMSCAN - SEM

ANSTO contributors

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- Dr Karin Soldenhoff
- Dr Chris Griffith

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Image:
(Above) Silicate minerals, a powerful additive. (Above left) Lynas Rare Earth's Kalgoorlie Rare Earth Processing Facility. Credit: Lynas Rare Earth.

ANSTO uranium technology solves the salinity challenge

THE CHALLENGE

Uranium is commonly recovered from ore bodies using sulfuric acid leaching. The dissolved uranium can then be recovered from the leach solution using an ion exchange (IX) process. The performance of the conventional IX process is negatively impacted by the presence of chloride. This can be problematic in Australia, where the high salinity of ground waters can pose an additional significant challenge to the economic recovery of uranium.

THE SOLUTION

ANSTO has long held an interest in this area and devised several potential solutions to the problem. In 2017, a targeted test work program was conducted for Boss Energy, examining the performance of a range of ion exchange resins as applied to the *in-situ* recovery project at Honeymoon, South Australia. The mine had historically operated for several years, but experienced several technical challenges, some of which related to the high salinity of its process waters.

The test work conducted at ANSTO identified a new-to-market, high-capacity resin that performed extremely well in saline leach liquors. The downside, however, was that while the resin extracted uranium from saline leach liquors very efficiently, it proved difficult to subsequently remove (elute) uranium from the resin. Conventional elution approaches led to the production of large volumes of dilute uranium solutions.

ANSTO's in-house research led to the development of a novel and highly efficient elution protocol using clever chemistry which involved the conversion of the extracted uranium complex on the resin from a sulfate to carbonate form. With this treatment, the uranium loaded on the resin responded well to chloride elution. An Australian innovation patent was granted for this technology.

THE IMPACT

The novel elution process was tested successfully for Boss Energy at ANSTO in a pilot plant in 2019 and was ultimately adopted for the full-scale plant at Honeymoon. The plant has been operating successfully since 2024, with annual production of over one million lbs of triuranium octoxide U3O8.



Image:
The in-situ Uranium Recovery Project in Honeymoon, South Australia.

Australian Research Priority or Futures Made in Australia Framework

- Building a secure and resilient nation
- Economic resilience and security

ANSTO strategic priority

- Deliver on Australia's priorities for the benefit of people, industry and the environment

Collaborators/clients

- Boss Energy

ANSTO contributors

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- Dr Tomasz Safinski

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Image:
ANSTO's Ion Exchange Onsite Test Rig.

Confirming a universal property in liquids

THE CHALLENGE

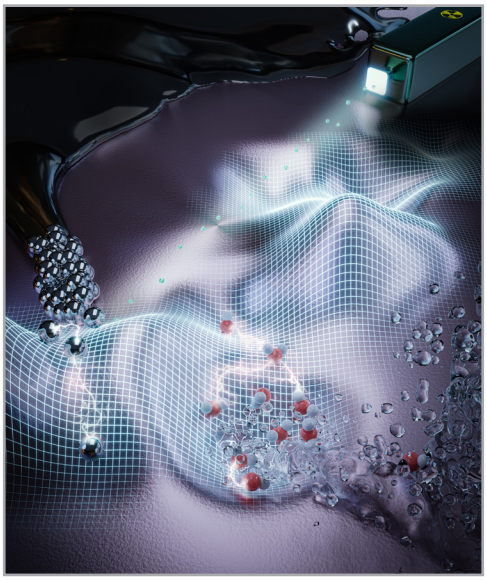
How heat can move through a material is determined by the 'vibrational density of states', which is a way of expressing all the movements or vibrations of the atoms in the material and the frequency at which they move. Understanding this for a solid material has been relatively easy, as the atoms are arranged in repeating units that can be more readily modelled. However, understanding this dynamic process in liquids has been extremely challenging, due to the much broader range of atomic motions available in a liquid. Not having this fundamental knowledge has held back the understanding of every and all liquids – from water through to olive oil.

THE SOLUTION

Recently, a mathematical expression of these states in a liquid was developed, but very little experimental data had been used to verify it. To do this, ANSTO scientists used a time-of-flight spectrometer to measure four different liquids. The liquids chosen to study had very different properties; water, two fluorinated oils and the metal gallium. If a single expression could describe the states, it could be confirmed as a universal law. The instrument can measure a broad spectrum of energies. With the measurements, the team were able to test how well the theory described the measurements.

THE IMPACT

The measurements fit to the theory very well giving the first confirmation of this universal law for liquids. The group showed that applying the theory does lead to a slight overestimation in the specific heat, which will need to be accounted for by future researchers. The law will play, for liquids, the same pivotal role that the comparable law, the Debye function, plays for solids and serve as the foundation for the whole research field involving liquids and beyond.



Australian Research Priority or Futures Made in Australia Framework

- Building a secure and resilient nation

ANSTO strategic priority

- Use of national research infrastructure
- Deliver on Australia's priorities for the benefit of people, industry and the environment

ANSTO capability/instrument

Australian Centre for Neutron Scattering
Pelican
Time of flight spectrometer

Collaborators

- University of Wollongong

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- Dr Dehong Yu

Paper DOI

doi.org/10.1021/acs.jpclett.2c00297

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Image:
An artist imagining of the experiment, neutrons directed at a liquid with waves of energy revealing the atomic behaviour. Image credit Hassan A. Tahini from Sciencebrush.

Controlling thermal expansion to improve materials

THE CHALLENGE

Most materials expand with increasing temperature, but there are some interesting exceptions. Exotic materials exist that can contract in volume or even show no volume change at all with increasing thermal energy, known as zero thermal expansion (ZTE) materials. ZTE materials are of interest because of their ability to withstand thermal shock. They can be used for precise machining and engineering tools such as micrometres, mirror substrates on Earth, or for space-based satellite application electronics where thermal issues can significantly affect performance.

ZTEs have in the past been synthesized by combining positive and negative expansion materials. Unfortunately, this typically requires high precision and arduous techniques to produce the composite, and it is challenging to ensure the combination is without defects. The solution is to discover single-phase ZTE materials. Although they are rare, the production and study of such materials offer a unique opportunity to characterise the atomic-scale arrangements that lead to zero thermal expansion, but also to potentially tune other thermal expansion behaviours.

THE SOLUTION

Earlier work conducted with neutron diffraction identified a promising uniform material ZTE. However, the high proportion of the element scandium in this original material would present substantial challenges for large-scale production. To explore the effect of the different elements, materials from 21 different combinations of elements were synthesised and characterised with high resolution diffraction and spectroscopy capabilities at ANSTO.

THE IMPACT

Two near-ZTE materials were identified. Additionally, the team were able to understand how the elements scandium and iron contributed to the thermal expansion properties of the family of compounds. This unique insight demonstrated the ability to tune the composition of materials to not only reveal zero thermal expansion, but also to synthesise low negative and positive thermal expansion materials.



Australian Research Priority or Futures Made in Australia Framework

- Building a secure and resilient nation

ANSTO strategic priority

- Use of national research infrastructure
- Deliver on Australia's priorities for the benefit of people, industry and the environment

ANSTO capability/instrument

Australian Centre for Neutron Scattering
Echidna
High Resolution Powder Diffractometer

Australian Synchrotron
MEXII
Medium Energy X-ray Absorption Spectroscopy
PD
Powder diffraction beamline

Collaborators/Clients

- University of NSW

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- Dr Helen Brand

Paper DOI

doi.org/10.1038/s41561-024-01514-1

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Image: (Adobe Stock)

Designing components for flexible robots

THE CHALLENGE

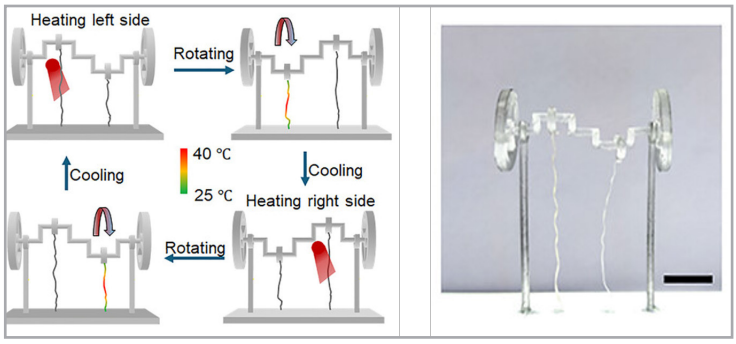
Soft robotics is a subfield of the wider robotics world where the robots are made from flexible rather than rigid materials. There is a wide range of uses for soft robotics, from surgical to exosuits, but their application has been held back by the need for technological development in soft actuators. An actuator is the component of a machine that moves when powered by an external input. In current soft robotics, these have been made from polymers. However, these systems are usually stimulated by high voltages (several kilovolts) or extreme temperatures (often exceeding 100 °C). Both pose serious limitations for next-generation soft robotic systems that are urgently needed for human medical applications.

THE SOLUTION

A group of researchers has investigated the possibility that liquid crystalline gels can be made into actuators. They designed the components at the atomic scale, arranging the molecules of the gel to have the properties they needed. These nanoscale molecule arrangements are very hard to measure, so the team used neutron small angle scattering capabilities to check that the molecules were lined up correctly. The materials were designed so that the molecules crosslinked within the gels, which gave the bulk material an ultra-high stretchability.

THE IMPACT

Once the liquid-crystalline microstructure was resolved across different length scales with small angle scattering, the team started the mechanical testing of their material. Here the gradient of the crosslinked molecules was key to the success of the material overall. It showed particularly good actuating properties when cycled through temperatures close to 37°C (body temperature). The group was able to construct a rotational, soft robotic driven by the actuators, which was made from crosslinked liquid crystals (see diagram below). This design of this type of actuator is a highly promising candidate for diverse applications, including biomedical devices, energy harvesting through movement and human–machine interfaces.



Australian Research Priority or Futures Made in Australia Framework

- Supporting healthy and thriving communities

ANSTO strategic priority

- Use of national research infrastructure
- Deliver on Australia's priorities for the benefit of people, industry and the environment

ANSTO capability/instrument

Australian Centre for Neutron Scattering
Quokka
Small angle scattering
Kookaburra
Ultra-small angle scattering
Xenocs
Small angle X-ray Scattering

Collaborators/Clients

- University of Wollongong

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Paper DOI

doi.org/10.1002/adma.202518370

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Image:
After designing their actuator material with the assistance of small angle scattering, the team designed a rotational device that demonstrated how they could work. The figure on the left demonstrates the rotating motion of the wheels via applying repeated heating sources to control the rotating device. The picture on the right is the actual device with a 5mm scale bar.

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Enhancing carbon composites for the aerospace industry

THE CHALLENGE

Advanced materials with exceptional performance and minimal structural weight are of paramount relevance in the aerospace industry. Carbon fibre reinforced composites offer lightweight high-performance solutions, due to their low density, and high tensile properties driven by the carbon fibre quality. Carbon fibre manufacturing is highly energy-intensive, resulting in high production costs and limited access to high-performance fibres. With very few overseas-based suppliers, there is a supply chain vulnerability to the Australian-based industry.

THE SOLUTION

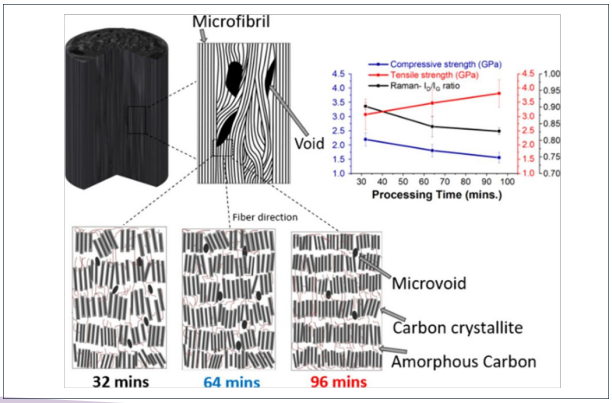
Carbon fibre production can be divided into three main stages: oxidation, carbonisation and surface modification. As up to 48% of energy is consumed during the stabilisation step, it is critical to explore avenues to reduce energy consumption towards low cost and more environmentally sustainable manufacturing while guaranteeing outstanding performance.

Researchers from Deakin University at the Carbon Nexus pilot line developed a scaled down version of a standard commercial production operation setup. This framework enables the manufacture of more economical and environmentally friendly carbon fibres with outstanding mechanical properties using tailored precursor polymers.

Synchrotron techniques and a filament analysis environment provided a robust characterisation, crystalline structure and defects in the novel carbon fibre. This information can inform process improvement. It demonstrated the capacity to control and even improve the mechanical properties of standard processes up to 27% in this new rapid stabilisation technology.

THE IMPACT

The use of a custom carbon fibre precursor (PAN co-polymer) in combination with a pilot scale carbon fibre manufacture line allowed investigators to systematically investigate the influence of stabilisation time on the structure, electrical conductivity and mechanical properties of the stabilised fibres and subsequent carbon fibres. The new product, 'rapid stabilisation fibres' exhibited an increasing 27% compressive strength than similar commercial options. These results have real potential to improve the production of carbon fibres with higher throughputs and pave the way for high performance, low-cost carbon fibres with enhanced mechanical performance.



Australian Research Priority or Futures Made in Australia Framework

- Building a secure and resilient nation.
- Transitioning to a net zero future.

ANSTO strategic priority

- Deliver on Australia's priorities for the benefit of people, industry and the environment

ANSTO capability/instrument

Australian Synchrotron
SAXS/WAXS
Small and Wide-angle X-ray Scattering beamline

Collaborators/clients

- Carbon Nexus pilot line
- Deakin University

ANSTO contributors

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Paper DOI

doi.org/10.1016/j.compositesa.2024.108524
doi.org/10.1016/j.mtcomm.2025.112329

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Image:
Schematic representation of the proposed carbon fibre microstructure at different processing conditions.

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Extracting more value out of Australia's lithium resources with new process

THE CHALLENGE

As global demand for lithium accelerates with the growth of electric vehicles and grid-scale energy storage, producers face a critical bottleneck: conventional hard-rock lithium processing leaves significant quantities of lithium unrecovered. Traditional refining of spodumene, the source mineral, depends on an energy-intensive thermal conversion step, in which ore is heated to around 1,000°C before acid leaching. This process works best only for higher-grade material and coarser particles. Fine spodumene concentrates and low-quality ores are often rejected to mine tailings, that results in substantial lithium losses—in some operations. As much as 30–50% of mined lithium units may not enter the supply chain.

THE SOLUTION

The LieNA® process introduces a fundamentally different extraction pathway for the processing of hard-rock lithium resources. Instead of relying on high-temperature roasting (>1,000°C), the process uses a hydrothermal caustic digestion method conducted in an autoclave at much lower temperatures (<300°C). By enabling the conversion to occur in solution, fine mineral material may be processed that would otherwise be blown out of a furnace. The lower conversion temperature significantly reduces energy intensity and processing costs to allow the treatment of material previously considered waste.

ANSTO's Minerals team has been developing the LieNA® process in collaboration with Livium Ltd (ASX:LIT) since 2015, which culminated in two pilot plant campaigns run over 25 days in 2024. The pilot plants converted spodumene to lithium phosphate, a mineral needed for lithium iron phosphate (LFP) cathode production, and demonstrated the performance of the technology under continuous, steady-state conditions at scale.

THE IMPACT

The successful execution of this work was a key milestone towards commercialisation of the LieNA® process. It was crucial to the establishment of a 50:50 joint venture between Livium and WA lithium miner MinRes in August 2025, which was formed to further develop this technology.

ANSTO continues to support this process and has recently refined the pilot plant to produce lithium phosphate to an ultra high purity battery specification and validated the performance of the technology with other low-grade mineral concentrates.



Australian Research Priority or Futures Made in Australia Framework

- Building a secure and resilient nation
- Critical and strategic minerals

ANSTO strategic priority

- Deliver on Australia's priorities for the benefit of people, industry and the environment

Collaborators/clients

- Livium Ltd

ANSTO contributors

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- Adrian Manis
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Image:
Final adjustments being made to the LieNA® piloting autoclave.

Insights on the origin of large gold nuggets

THE CHALLENGE

Although the process of gold deposition is well known, how large gold nuggets are formed in nature is still not clear. Gold is only dissolved in natural fluids at around one part per million, so how does it concentrate into lumps that weigh tens or even hundreds of kilograms?

The dense, yellow metal is often found in veins of the rocky mineral quartz. This is because the two condense together from hot fluids underground by changes in temperature, pressure and chemistry. Could the properties of quartz cause the gold to accumulate into nuggets? Quartz does have a strange property, in that it is piezoelectric, meaning that when individual particles of quartz or grains are put under stress, they generate an instantaneous electric charge.

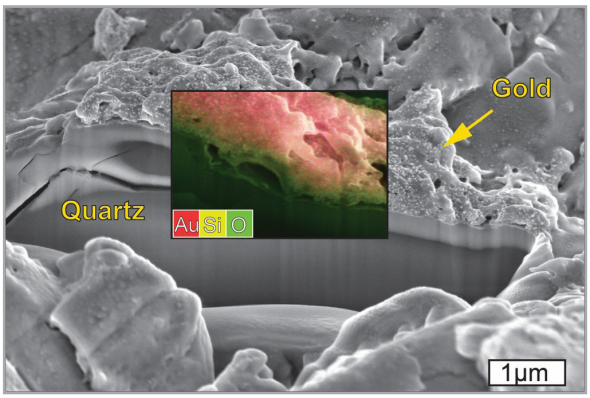
THE SOLUTION

The researchers used neutron strain scanning to investigate how the quartz particles were aligned in a series of samples from the Fosterville gold deposit in Victoria. These samples were 2 cm^3 and needed the highly-penetrating properties of neutrons to investigate the whole sample. The results showed that there was a variation in the direction of the quartz grains across the samples. The researchers found that the quartz was not the same throughout the gold deposit and some areas behaved differently from others.

THE IMPACT

The research team then undertook experiments to simulate the effects 'rattling' a quartz crystal would be subject to during an earthquake. This involved submerging quartz crystals in gold-bearing fluids and then applying back-and-forth stress to the crystal with a motor. Each time the motor head hit the quartz, it generated a voltage.

Afterwards, the quartz samples were investigated with an electron scanning microscope and confirmed gold had been deposited on the surface. In fact, once the process began it was shown that gold was more likely to be deposited on existing gold grains. This work delivered a better understanding of how large gold nuggets are formed and can potentially improve prospecting.



Australian Research Priority or Futures Made in Australia Framework

- Building a secure and resilient nation

ANSTO strategic priority

- Use of national research infrastructure

ANSTO capability/instrument

Australian Centre for Neutron Scattering
Kowari
Strain scanner

Collaborators/clients

- Monash University

ANSTO contributors

- Dr Valdimir Luzin

Paper DOI

doi.org/10.1038/s41561-024-01514-1

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Image:
A scanning electron microscope image shows nanoparticles of gold forming on quartz. Image credit: Christopher Voisey.

Looking inside batteries to prevent catastrophic failure

THE CHALLENGE

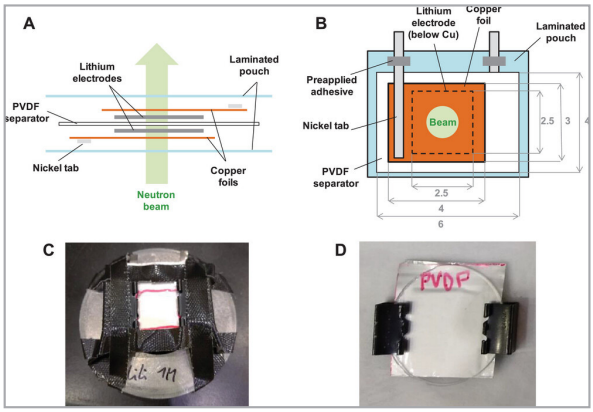
Lithium metal batteries could store far more energy than today's lithium-ion batteries, making them promising for electric vehicles, portable electronics and grid-scale energy storage. However, during charging, metallic lithium can form needle-like and porous structures known as whiskers, moss and dendrites at electrode surfaces. These structures increase surface area, accelerate unwanted reactions, consume active lithium and can cause short circuits or catastrophic failure. Until now, researchers lacked a non-destructive way to directly measure how lithium structures grow, dissolve and transform inside working batteries under realistic operating conditions.

THE SOLUTION

This ANSTO-led study demonstrated that ultra-small-angle and small-angle neutron scattering can directly measure metallic lithium deposits inside working lithium metal batteries without the need to dismantle the cell. The team studied symmetrical pouch cells during charging and discharging, isolating the lithium across a large electrode area that was representative of the whole battery. The measurements measured the surface area and average distances between lithium–electrolyte interfaces and revealed features at micrometre and nanometre length scales. Importantly, the smaller structures contributed most of the total lithium surface area, and their size and surface area changed with current density and cycling history. This data revealed insights into how damaging deposits evolve with powering up and down the batteries.

THE IMPACT

This work provides a powerful new way to study one of the key barriers to safer, higher-energy rechargeable batteries. By measuring lithium growth non-destructively inside operational cells, researchers can now investigate how current, charge duration and repeated cycling affect the formation of structures and irreversible surface changes. This knowledge is essential for designing lithium metal batteries that are safer, longer-lasting and more reliable for transport, electronics and clean-energy storage. The approach also demonstrates how ANSTO's neutron scattering capabilities can solve applied energy-storage challenges that are difficult to address using microscopy, X-ray imaging or gas adsorption alone.



Australian Research Priority or Futures Made in Australia Framework

- Transitioning to a net zero future
- Supporting healthy and thriving communities
- National Battery Strategy

ANSTO strategic priority

- Use of national research infrastructure
- Deliver on Australia's priorities for the benefit of people, industry and the environment

ANSTO capability/instrument

Australian Centre for Neutron Scattering
Kookaburra
Ultra-small angle scattering
Quokka
Small angle scattering

ANSTO contributors

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- Prof. Elliot P. Gilbert
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Paper DOI

doi.org/10.1002/aenm.202301266

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Image:
In situ lithium pouch cell used for neutron scattering measurements, showing the cell layout, neutron beam path and sealed electrolyte-wet PVDF separator held between quartz plates.

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Microgravity reveals insights for advanced materials

THE CHALLENGE

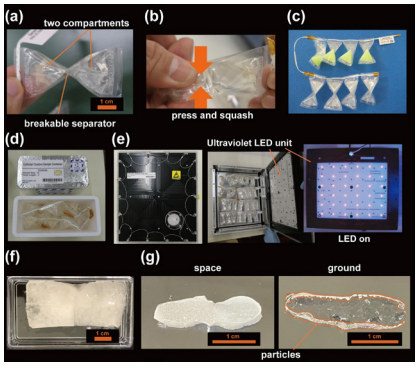
Colloids, tiny particles suspended in a liquid, are central to materials used in pharmaceuticals, photonics, optoelectronics, sensing, clinical diagnostics and industrial products. When oppositely charged particles attract, they can self-assemble into small clusters, including structures that may act as building blocks for photonic crystals. On Earth, even slight sedimentation and convection can disturb how micron-sized particles move, meet and organise, especially dense titania particles. Researchers needed microgravity to reveal the fundamental interactions controlling cluster formation.

THE SOLUTION

This international study led by Nagoya City University, with Japan Space Forum, Advance Engineering Services, JAXA and ANSTO, investigated how positively and negatively charged colloidal particles cluster in the microgravity environment of the International Space Station. Special two-compartment sample bags allowed particle suspensions to be mixed in orbit, left for two days to form clusters, then immobilised in an ultraviolet-cured gel and returned to Earth. Optical microscopy showed that polystyrene clusters formed in space had an average association number about 50% larger than ground controls and showed better molecular symmetry. Electrostatic clustering and aggregation in complex structures were observed in high density titania particles only under microgravity, which also suppressed sedimentation. Small- and ultra-small-angle neutron scattering data across 1 nanometre to 10 micrometres confirmed trends in cluster sizes.

THE IMPACT

The study shows that gravity can significantly alter the self-assembly of colloidal particles even particles with density close to water. By removing sedimentation and convection, microgravity revealed how electrostatic attraction, charge screening and particle density influenced cluster size, symmetry and aggregate structure. This knowledge supports better models for designing advanced materials, including photonic crystals, optical devices, sensing technologies, clinical diagnostics and improved drug formulations. The work also earned NASA recognition and featured in NASA's 2024 *Annual Highlights of Results from the International Space Station.* This study demonstrated how space-based experiments combined with neutron scattering can generate materials insights that are difficult to obtain on Earth.



Australian Research Priority or Futures Made in Australia Framework

- Transitioning to a net zero future
- Supporting healthy and thriving communities

ANSTO strategic priority

- User of national research infrastructure
- Deliver on Australia's priorities for the benefit of people, industry and the environment

ANSTO capability/instrument

Australian Centre for Neutron Scattering
Kookaburra
Ultra-small angle scattering
Quokka
Small angle scattering

Collaborators/clients

- Nagoya City University
- Japan Space Forum
- Advance Engineering Services
- Japan Aerospace Exploration Agency
- International Space Station/Japanese Experiment Module "Kibo" research program

ANSTO contributors

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Paper DOI

doi.org/10.1038/s41526-023-00280-5

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Image:
Experimental setup for the microgravity clustering study. (a) Sample bag with two compartments and breakable separator. (b) Mixing by squeezing. (c) Flight sample prepared for handling in microgravity. (d) Sample bag in shipping container. (e) UV irradiation system for gel fixation. (f) Returned titania sample. (g) Cross-sections showing uniform space sample and sedimented ground control.

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New material has useful magnetic properties for devices

THE CHALLENGE

Materials without a defined shape, amorphous materials can have advantages over crystalline or solid, ordered materials for new spintronic and data storage technologies as the irregular arrangement of atoms can enhance how spins, charges and magnetic regions behave.

Topological devices have an unusual property in that they can insulate on the inside and conduct on the outside.

A special form of conductivity is critical to the performance of these high-efficiency topological spintronic devices. This effect is characterised by a transverse electric current, in which electric field lines are perpendicular to the direction of the current flow, even in the absence of an external magnetic field.

THE SOLUTION

Researchers found that a new material made of cobalt, magnesium and gallium, behaves in a very similar way to its more ordered form, even though its internal structure is less organised. This means it can still maintain strong magnetic properties.

The study showed that the material has stronger magnetic performance than expected and works well at everyday temperatures.

These findings suggest it could be useful for future data storage technologies, helping store large amounts of information in a small space.

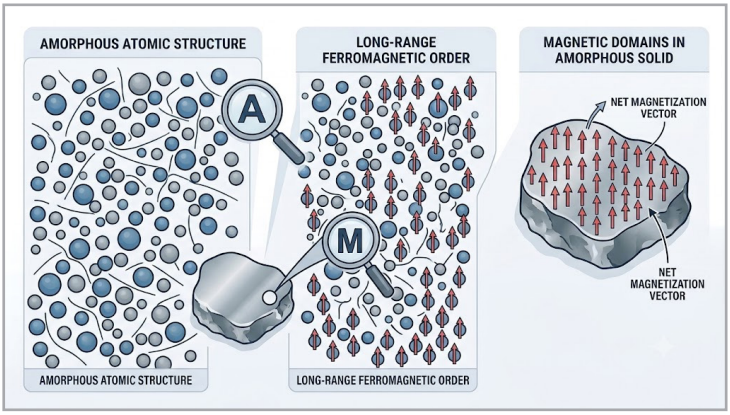
THE IMPACT

This study showed that the new material could be useful in future electronic technologies.

Because the material is easier to make than many existing alternatives, it could help reduce manufacturing costs and make large-scale production simpler.

This has the potential to significantly improve the scaled-up manufacturing process of magnetic memory devices.

The findings open up new possibilities for developing advanced materials that can be used in practical, real-world technologies, including future data storage devices.



Australian Research Priority or Futures Made in Australia Framework

- Economic resilience and security

ANSTO strategic priority

- Use of national research infrastructure research
- Deliver on Australia's priorities for the benefit of people, industry and the environment

ANSTO capability/instrument

Australian Centre for Neutron Scattering
Taipan
Triple axis spectrometer
Platypus
Neutron Reflectometer

Collaborators/clients

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- Dr Yuefeng Yin
- Dr Kaijian Xing
- Dr Shengqiang Zhou
- Dr Abdulhakim Bake
- Dr Golrokh Akhgar
- Lei Chen
- Prof Xiaolin Wang
- Prof Nikhil V. Medhekar
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Paper DOI

doi.org/10.1016/j.matt.2025.101988

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Image:
An example of a structurally disordered, amorphous material with coherent magnetic properties leading to long range ferromagnetic order.

New revelations on sword manufacture in ancient kingdom

THE CHALLENGE

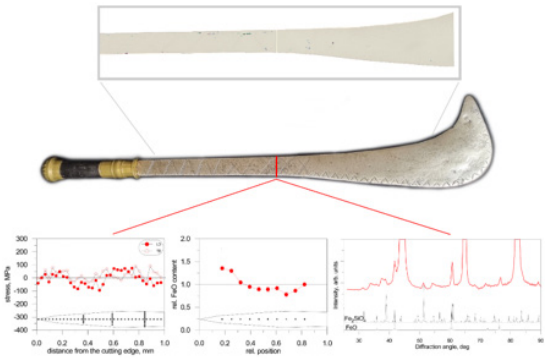
The Kingdom of Dahomey, now part of the Republic of Benin, was a unique centralised state on the Bight of Benin in West Africa, composed of people who identified ethnically as Fon, and occupying part of a coastal region that came to be called the Slave Coast. Spanning almost three centuries, from the early 17th to the late 19th centuries, Dahomey was among the most effective military powers in the region for most of that duration. It is well known that many European weapons, including guns and cannons, were routinely imported into the kingdom from its very early history in the 1600s right up until its fall to the French in the 1890s. However, it is far more uncertain whether the unique swords of the kingdom were being made locally or being custom-ordered through foreign cutlers. Both possibilities have intriguing implications for the history of the kingdom.

THE SOLUTION

Based on a provenance preceding UNESCO's *1972 Convention concerning the Protection of World Natural and Cultural Heritage*, six Dahomean swords were selected for this research. Neutron tomography, powder diffraction full pattern analysis and residual stress measurement are well-established tools for scientific analysis, especially on heritage objects, where non-destructive approaches are essential. Neutron beams have a high penetration power that is ideal for surveying most cultural heritage specimens in a non-invasive way. The neutron, a heavy uncharged particle that interacts primarily with the atomic nuclei, enables it to probe most materials below the surface of objects, sometimes to a depth of even tens of centimetres.

THE IMPACT

The combination of findings across the three techniques suggests that all six Dahomean blades were locally made by African smiths and fall into two technological groups: highly refined, low-porosity blades produced by extensive forging or annealing, and intentionally folded blades with layered welds and higher porosity, reflecting distinct but skilled local practices. These results provide new evidence for Indigenous iron production and trade in pre-colonial West Africa and clearly distinguish Dahomean metallurgy from European swordmaking, which relied on higher-carbon steels and different processing and heat-treatment regimes.



Australian Research Priority or Futures Made in Australia Framework

- Elevating indigenous knowledge systems

ANSTO strategic priority

- Use of national research infrastructure

ANSTO capability/instrument

Australian Centre for Neutron Scattering
Dingo
Neutron Imaging
Kowari
Strain Scanner
Wombat
High-intensity diffraction

Collaborators/clients

- The University of Sydney

ANSTO contributors

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- Prof Max Avdeev
- Dr Vladimir Luzin

Paper DOI

doi.org/10.3390/heritage8020062

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Image:
Tomographic reconstructed cross-sections of one Dahomean sword (top) from Dingo data. The red line indicates the locations of stress measurements with the Kowari instrument (bottom left) and diffraction pattern from Wombat (bottom right). The centre bottom plot shows the FeO secondary-phase distribution across the blade width.

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Pinpointing weak spots in computer chips bound for space

THE CHALLENGE

Space is a harsh environment for electronics. High-energy particles constantly strike spacecraft, flipping stored data and sometimes crashing onboard computers. Manufacturers screen chips for space by exposing devices to radiation, but modern chips pack millions of components into a few square millimetres. A radiation test on the whole device cannot show which part of the chip actually failed. Focused ion beams and pulsed lasers can probe one tiny region at a time. However, no one had properly confirmed that their results match the standard tests used by space agencies. That gap limits radiation testing for the next generation of space electronics.

THE SOLUTION

ANSTO and University of Saskatchewan researchers used the Heavy Ion Nuclear Microprobe beamline to perform a radiation test on a specialised radiation-hardened microcontroller, StarRISC, one region at a time. Because the microprobe focuses its beam to less than a thousandth of a millimetre, the team could irradiate the chip's memory, processing core and timing circuits separately. They watched how each responded and compared the results with pulsed laser and conventional broad-beam tests on advanced nanometre chips. The result was clear. Most system crashes traced back to errors building up in the chip's onboard memory, while the processing core and support circuits contributed almost nothing. Different memory blocks failed at different rates, depending on their use. More intense particle bombardment sharply increased the risk of crashes. The study confirmed that microprobe testing on an accelerator can locate a chip's weak points in a way whole-device testing cannot.

THE IMPACT

The study gives the space industry evidence that microprobe testing can isolate exactly where a chip fails under radiation. Designers can harden the memory blocks that matter most instead of over-engineering entire devices. The published results, also presented at international conferences, strengthened confidence in laser and microbeam methods for qualifying space electronics. The process could prove that hardware can survive a space flight. The research also confirmed ANSTO's Centre for Accelerator Science could be used by developers to test and improve space-bound designs. This outcome supports sovereign Australian capability in space electronics and radiation qualification under the Australian Government's Future Made in Australia agenda. The collaboration also trained a PhD researcher in the use of these specialised techniques.

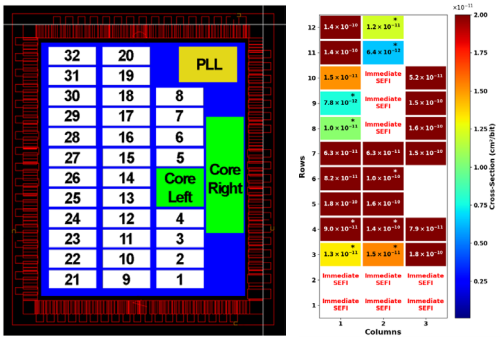

Image:
(Left), the StarRISC chip layout with its memory blocks labelled. (Right), measured error rates for individual memory blocks tested with silicon ions.

Australian Research Priority or Futures Made in Australia Framework

- Building a secure and resilient nation

ANSTO strategic priority

- Deliver on Australia's priorities for the benefit of people, industry and the environment

ANSTO capability/instrument

Centre for Accelerator Science
6MV SIRIUS Accelerator
Heavy Ion Nuclear Microprobe beamline

Collaborators/clients

- University of Saskatchewan (Canada)
- Prof Li Chen
- Chris Elash (PhD student)

ANSTO contributors

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- Dr Ryan Drury
- Dr Zeljko Pastuovic

Paper DOI

doi.org/10.1109/TNS.2026.3655735

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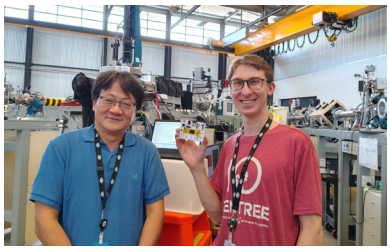

Image:
Prof Li Chen and PhD student Chris Elash at ANSTO's Centre for Accelerator Science with the StarRISC chip before irradiation on the SIRIUS heavy ion microprobe.

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Radioactivity removal patent for critical minerals

THE CHALLENGE

A key radioactive contaminant, actinium-227 (Ac-227), is released during the processing of many rare earth deposits and is highly challenging to separate from the valuable rare earths. If not removed, contamination of the final products will occur, which is problematic for the downstream processing steps leading to magnet manufacture. To date this issue is addressed in the downstream separation refinery using complex solvent extraction technology, but this approach presents a significant barrier for many developing rare earth projects.

THE SOLUTION

The patented technology developed at ANSTO allows removal of a large proportion of the Ac-227 through a simple co-precipitation process that can be readily integrated into existing rare earth hydrometallurgical processes at low cost and with minimal modification of the plant layout.

THE IMPACT

This invention has the potential to impact the rare earth supply chain landscape by empowering developing projects to produce a saleable, low Ac-227 intermediate product without engaging in costly and complex separations. It represents a 'first of its kind' method of dealing with Ac-227 that has garnered significant global interest. Several of ANSTO Minerals commercial clients are engaged in testing of the technology at ANSTO. The invention strongly aligns with the federal government's strategic commitment to growing Australia's sovereign capability in the processing of critical minerals and promotes ANSTO's global reputation as a leading technology provider in rare earth processing.





Australian Research Priority or Futures Made in Australia Framework

- Growing Australia's sovereign capability in critical minerals processing
- Building a secure and resilient nation

ANSTO strategic priority

- Deliver on Australia's priorities for the benefit of people, industry and the environment

ANSTO capability/instrument

Radioactivity management
Gamma spectrometry
Ac-225 tracer

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- Dr James Quinn
- Dr Elizabeth Ho

Paper DOI

doi.org/10.2139/ssrn.6591352

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Image:
ANSTO patent allows removal of radioactive contaminant in critical minerals processing.

Supporting the development of the next generation of hair-care products

THE CHALLENGE

The healthiness of our hair is connected to a lipid layer that covers the proteins at the core of each strand; a layer that can be damaged by weathering and bleaching. Though the composition of this lipid layer varies a lot between hair types, the most abundant component is a long chain fatty-acid molecule, known as a lipid. This particular lipid has a branch towards one end of its structure, a critical feature that may govern many hair properties. Understanding how shampoo ingredients, such as polymers and surfactant, interact with this lipid is essential for the cosmetic industry to improve the performance of its products. Additionally, a current challenge is to increase the sustainability of shampoo products by including more natural or bio-sourced and biodegradable ingredients without losing the desired cosmetic performance of current formulations.

THE SOLUTION

Neutron reflectometry is an ideal technique to study layers on a surface, and to characterise the connections between these layers. But how is this used to study hair? You cannot just put a strand of hair in a scientific instrument. It is far too thick! Researchers developed three surfaces that have similar chemical features to the acid of interest, which could be studied with this technique. They then conducted experiments that treated these surfaces with a range of simplified shampoo-like formulations. The samples were deuterated, substituting deuterium for the hydrogen atoms. During the experiments, conducted at ANSTO and in France, they monitored how the hair model surfaces changed and what was absorbed onto the surfaces with treatment and rinsing.

THE IMPACT

The hair model surfaces that were developed (two to model healthy hair and one to simulate damaged hair) were successfully characterised and showed different responses to the applied formulations. The research showed that the layers absorbed from the treatments were not all removed on rinsing, a desired property when using hair-care products. It demonstrated that the model surfaces could re-create the response of different approaches to hair-care. They were able to show differences in how ingredients of natural and of petrochemical origin were absorbed, which helps support the transition to more sustainable formulations.



Australian Research Priority or Futures Made in Australia Framework

- Supporting healthy and thriving communities

ANSTO strategic priority

- Use of national research infrastructure

ANSTO capability/instrument

Platypus
Neutron reflectometer
Australian Centre for Neutron Scattering
National Deuteration Facility
Chemical Deuteration

Collaborators/clients

- KTH Royal Institute of Technology, Sweden
- L'Oréal Research and Innovation, France

ANSTO contributors

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Paper DOI

doi.org/10.1039/D4SM00784K

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Image: Close view of a strand of hair. (Adobe Stock)

Synchrotron light illuminates plant health

THE CHALLENGE

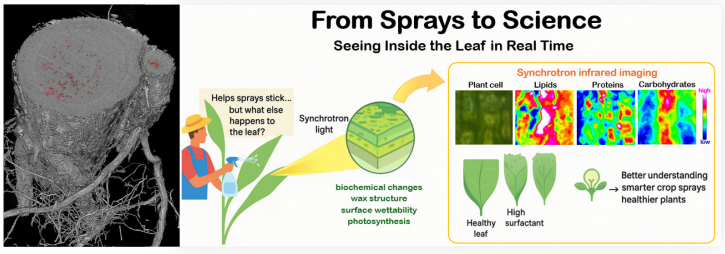
Crop productivity depends on plant health above and below ground; yet both are difficult to study under real agricultural conditions. The balance between beneficial and damaging surfactant use on leaves is poorly understood, as excess application can disrupt leaf waxes, photosynthesis and yield. Suboptimal root growth in soils costs billions of dollars annually, but roots are the 'hidden half' of plants as traditional methods are destructive and unable to capture true 3D structure in natural soils. Existing *in situ* techniques are limited.

THE SOLUTION

Researchers are using complementary synchrotron imaging techniques to study whole-plant health from root to tip. High-resolution infrared imaging provides non-destructive, real-time, *in vivo* tracking of biochemical changes inside living maize leaves following the application of surfactant. Combined with computational analysis, this reveals how surfactants alter leaf waxes and maintain contact with and spread across the surface and key biochemical components of photosynthesis. In parallel, synchrotron X-ray tomography enables high-resolution, three-dimensional imaging of root systems in large, intact soil cores collected from the field. This preparation preserves natural soil structure and captures root distributions realistically. Ongoing work focuses on optimising imaging factors and developing robust data-processing pipelines to support widespread use of these methods.

THE IMPACT

This research makes previously invisible plant processes visible. It provides a whole-of-plant perspective on crop health. Farmers and industry can now identify when surfactant use shifts from beneficial to harmful and guide improved spray formulations and application rates. High-resolution root imaging reveals how soil conditions influence root growth to inform better soil and crop management. Together, these insights support a more efficient use of inputs, improved yields and reduced environmental impact to support more productive, profitable and sustainable agricultural systems.



Australian Research Priority or Futures Made in Australia Framework

- Protecting and restoring Australia's environment

ANSTO strategic priority

- Use of national research infrastructure
- Deliver on Australia's priorities for the benefit of people, industry and the environment

ANSTO capability/instrument

Australian Synchrotron
IMBL
Imaging and Medical Beamline
IRM
Infrared Microspectroscopy

Collaborators/clients

- Geoderma
- Deakin University
- RMIT University

ANSTO contributors

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- Dr. Annaleise Klein
- Dr. Pimm Vongsvivut
- Dr. Daniel Hausermann

Paper DOI

dx.doi.org/10.1111/tpj.70227

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Image:
(Left) CT of root system; (right) infrared imaging of surfactant.

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Synchrotron science powering the next generation of energy storage

THE CHALLENGE

Advanced batteries are essential for the transition to clean energy—powering everything from electric vehicles to large-scale renewable energy storage. However, improving battery performance remains challenging because the processes that control efficiency, lifetime and safety occur deep inside operating batteries and are largely invisible to conventional analytical techniques. Chemical reactions at electrode surfaces, changes in atomic structure, material degradation and the movement of charged ions can all influence battery performance. Without the ability to observe these processes in real time, developing longer-lasting, safer and higher-performance energy storage technologies remains a significant scientific challenge.

THE SOLUTION

Researchers combined four advanced synchrotron techniques at the Australian Synchrotron to uncover how next-generation batteries function during their operation. A novel and advanced technique enabled real-time monitoring of chemical reactions occurring at the electrode–electrolyte interface, revealing processes that influence battery stability and lifetime.

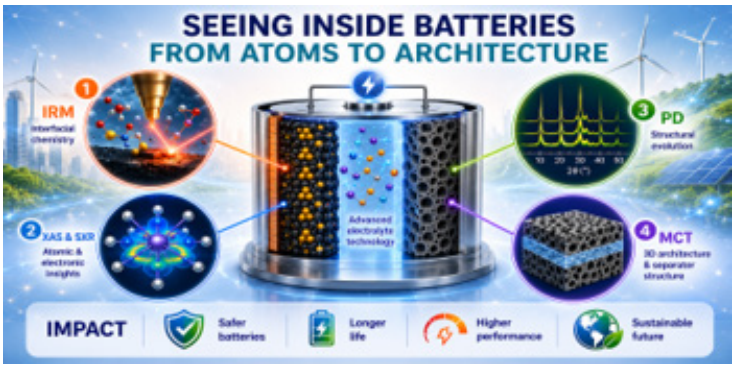
Complementary measurements on other beamlines revealed how atomic structure, electronic states and material transformations govern battery performance. Micro-computed tomography provided 3D visualisation of internal battery architectures and separators without damaging the device.

Together, these capabilities delivered an unprecedented view of battery behaviour across multiple length scales, linking atomic-level processes with device performance and providing critical insights for the design of safer, longer-lasting and higher-performance energy storage technologies.

THE IMPACT

For the first time, researchers could follow critical battery processes across multiple length scales from atomic interactions and interfacial chemistry to the 3D architecture of complete battery components. These insights help accelerate the development of safer, longer-lasting and higher-performance batteries needed for electric vehicles and renewable energy storage.

By enabling scientists to see inside working batteries with unprecedented detail, ANSTO is helping unlock the next generation of energy storage technologies that will support a cleaner, more sustainable future.



Australian Research Priority or Futures Made in Australia Framework

- Transitioning to a net zero future

ANSTO strategic priority

- Use of national research infrastructure
- Deliver on Australia's priorities for the benefit of people, industry and the environment

ANSTO capability/instrument

Australian Synchrotron
IRM
Infrared Microspectroscopy
XAS
X-ray Absorption Spectroscopy
PD
Power Diffraction
SXR
Soft X-ray Spectroscopy

Collaborators/clients

- Professor Shi-Zhang Qiao, Adelaide University
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- A/Professor Wei Kong Pang, Adelaide University
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Synchrotron techniques used to enhance crop productivity

THE CHALLENGE

Maintaining productive and resilient agricultural soils is increasingly challenging as farming systems face declining nutrient availability, soil degradation and the need to improve long-term soil health. Supporting plant growth in poor, degraded or structurally unstable soils requires a deeper understanding of how nutrients are retained, transformed and made available to crops.

Sulfur is an essential plant nutrient required for key biological functions, including chlorophyll synthesis and the formation of amino acids. However, global reductions in inorganic sulfur inputs are contributing to declining sulfur availability in agricultural soils. Although most sulfur in soil occurs in organic forms, plants primarily take up sulfur as inorganic sulfate, making sulfur cycling and mineralisation critical to crop productivity.

Understanding how organic additives, soil carbon, pH, and soil structure influence nutrient cycling is essential for developing sustainable agricultural practices and improving the performance of both degraded terrestrial soils and challenging matter, such as dust and crushed rock.

THE SOLUTION

Researchers from the University of Adelaide used Micro-computed tomography (MCT), a synchrotron-based technology, to investigate how soil organic carbon is preserved and how soil structure develops. High-resolution, three-dimensional imaging of roots and soil at the microstructural level were produced. Scientists can quantify changes in root distribution, porosity and regolith density from these images. This could contribute to innovative soil additives to transform regolith into a medium suitable for plant growth.

Complementing this work, soil samples from the world's longest running agricultural experiments, spanning 145 years, were analysed using an X-ray absorption spectroscopy technique to understand the effects of long-term land use on different forms of sulfur. Incidence of sulfur deficiency has increased since the 2000s and is expected to increase long term. The addition of farmyard manure has resulted in more soil organic carbon, and more total sulfur with a higher proportion of reduced organic sulfur. Research revealed that a slow-release form of sulfur for crops was better than the long term addition of sulfur-containing mineral fertilisers.

THE IMPACT

This research supports Australia's national priorities in agricultural productivity, environmental sustainability and climate resilience. By combining microscale soil structure imaging with long-term nutrient analysis, researchers can better understand how organic additives influence soil health, nutrient retention and plant growth over time. By advancing the understanding of soil biochemical processes, this research contributes to more sustainable evironmental farming practices, improved crop productivity and long term soil restoration.

Australian Research Priority or Futures Made in Australia Framework

- Agriculture

ANSTO strategic priority

- Use of national research infrastructure
- Deliver on Australia's priorities for the benefit of people, industry and the environment

ANSTO capability/instrument

Australian Synchrotron
MCT
Micro-Computed Tomography
MEX1 & MEX 2
Medium Energy X-ray Absorption Spectroscopy

Collaborators/clients

- University of Adelaide
- University of Queensland
- Rothamsted Research, UK

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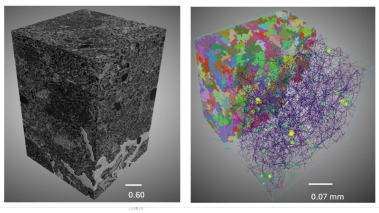

Image:
A CT image obtained from the MCT beamline, showing microstructure of soil and roots (left), along with pore network analysis (right), will be used to quantify changes in pore size distribution, connectivity and aggregate stability.

Understanding the drought tolerance of Australian native fruits

THE CHALLENGE

One of the biggest challenges of food and crop science is to provide nutrition to growing populations through sustainable agriculture while climate change threatens crop yields. Australian native fruits, which have evolved to tolerate harsh conditions have long histories of cultivation and use by First Nations Australians. Key to their drought tolerance is likely to be from their unique water-binding properties. Water influences microbial and structural stability, so the atypical behaviour of water in native fruits required further investigation to potentially shed light on the resilience of Australian native fruits to drought stresses.

THE SOLUTION

Neutron spectroscopy is an excellent technique for discovering how water is bound up in materials, and crucially how free it is to leave (dehydrate). It is a valuable tool for studying the structure and dynamics of organic materials, including food.

In the study, the dynamics of four diverse and commercially relevant Australian native fruits were studied: muntries, riberries, finger limes and Kakadu plums. A conventionally available fruit not native to Australia, the apple, was chosen for the control.

THE IMPACT

Experiments revealed that, in contrast to the apple, each of the Australian native fruits contained water that was bound to the biopolymer within the fruit in a distinctly different way. The water dynamics of Australian native fruits were consistent in that the translation of strongly bound water was slower than other fruit: up to 61% slower than in the apple. Free water within the fruit was more accelerated on the other hand, translated by as much as 24% faster than in an apple and 13% faster than pure water. The work linked these measurements with drought-stress markers. The research indicates that the water dynamics are related to the drought-tolerance of Australian native fruit, as well as their increased energy to dry. Knowing this link between water dynamics and drought tolerance will help us assess what fruit can survive in future climates.



Australian Research Priority or Futures Made in Australia Framework

- Supporting healthy and thriving communities
- Elevating Aboriginal and Torres Strait Islander knowledge systems

ANSTO strategic priority

- Use of national research infrastructure
- Deliver on Australia's priorities for the benefit of people, industry and the environment

ANSTO capability/instrument

Australian Centre for Neutron Scattering

Emu

High-resolution backscattering spectrometer

Pelican

Time-of-flight spectrometer

Collaborators/clients

- Monash University
- Australia National University

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Image:
Australian finger limes (Adobe Stock)

Unusual electronic properties in magnetic materials could be used for spintronic computing

THE CHALLENGE

Current research on spintronic materials has the potential to revolutionise computing. Traditional electronic computing uses the charge of electrons to transmit information by moving the electron through the computer—which often results in wasted heat energy, as anyone who has used their laptop on their lap will know. Instead, researchers are investigating using a different property of electrons, their spin, to transmit information. This is a quantum property, but critically, spin can transmit information over vast distances more rapidly than charge and without the waste heat, making spintronics a highly energy-efficient technology of the future.

Additionally, researchers aim to exploit an unusual property known as the spin Seebeck effect, in which the direction and rate of temperature in a magnetic material generates a spin current that can be converted into a voltage without the need for an electron charge to move through the material.

The spin Seebeck effect is key to the development of spintronics devices, as it will allow us to measure and manipulate spin currents, and could pave the way for future spintronic computing. At present, this effect is poorly understood. Researchers from Japan and Australia investigated a potential new spintronic material, terbium iron garnet, at ANSTO.

THE SOLUTION

Neutron scattering is the ideal way to measure spintronic behaviour. Neutrons can investigate the bulk of a material but are also sensitive to magnetic structure and spin excitations. They can measure tiny changes when controlling the temperature and external magnetic field. Furthermore, neutron beams can be polarised in one direction with filters to measure the orientation of the spins within the material.

As a spintronic material, terbium iron garnet, was predicted to exhibit a reversal of the spin current direction at a critical temperature. To make the first observation of this spin current reversal, experiments were undertaken using neutrons and neutron polarisation. The experiment was complex, but the team observed the reversal at around -24 °C, which provided a clear validation of the complex spin-wave models used to understand this material.

THE IMPACT

Understanding this spin effect could eventually lead to several groundbreaking outcomes, including the ability to harvest electrical power from waste heat. For spintronic applications, quantifying and controlling currents from collective excitations in spintronic materials provides the framework for designing and building spin-based computing devices. Harnessing the spin effect could be crucial to realising the full potential of spintronic computing. This work has deepened our understanding of the behaviour of spintronics materials, a prerequisite for the integration into novel technologies, which will drive innovation while transitioning to a net zero future.

Australian Research Priority or Futures Made in Australia Framework

- Transitioning to a net zero future

ANSTO strategic priority

- Use of national research infrastructure
- Deliver on Australia's priorities for the benefit of people, industry and the environment

ANSTO capability/instrument

Australian Centre for Neutron Scattering
Taipan
Triple axis spectrometer
Helium 3 Polariser

Collaborators/clients

- Tohoku University
- University of Tokyo
- Japan Atomic Energy Agency
- RIKEN Center for Emergent Matter Science
- Japan Science and Technology Agency
- High Energy Accelerator Research Organization
- Comprehensive Research Organization for Science and Society

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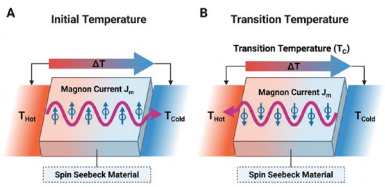

Image:
An example of how the magnon current Jm in a spin Seebeck material reverses when the material crosses a transition temperature.

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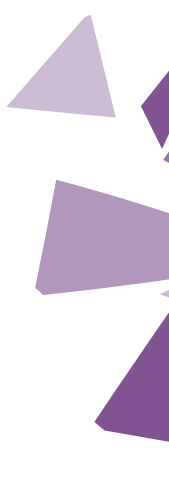



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