STUDENT PROJECTS

2021 / 2022

AINSE

THE AUSTRALIAN INSTITUTE OF NUCLEAR SCIENCE AND ENGINEERING

AINSE

THE AUSTRALIAN INSTITUTE OF NUCLEAR SCIENCE AND ENGINEERING

Playing a leading role in nuclear Education and training

Stimulating and supporting students and early career researchers in pursuing a career in nuclear science and engineering

Facilitating Collaborations with researchers at ANSTO's landmark infrastructure

Providing an effective Network between all stakeholders of nuclear science and engineering

Engaging with Members to enhance funding opportunities and ensure relevance of nuclear science and engineering

What is the Student Project Book?

The purpose of this book is to showcase projects available at ANSTO to students interested in collaborating in Honours, Masters or Ph.D. projects with ANSTO researchers.

Students interested in a project in the book can contact the researcher(s) directly via the contact details listed in the project details.

If you are unsure who to contact regarding any of the projects, please contact an AINSE staff member who can help connect you with the relevant researchers at ANSTO. Email us at enquiries@ainse.edu.au, or chat with us on +61 2 9717 3376.

How do I get involved with a project that I like?

1. Read through the project booklet and select the project(s) you are interested in.

2. Contact the ANSTO representative on the project(s) to discuss, either during the **Research Roundup Networking Event** at the end of the Winter School, or by using the contact details listed in the project details.

3. If the project is suitable, locate a supervisor at your university to support the project(s) – the research office at your university may be able to assist you;

NOTE: Projects marked with an * in the title are already linked to a specific university collaborator. The university supervisor, their university, and their contact details will be listed in the project's Contact section.

4. If successful in collaborating on a project(s), students from AINSE member institutions are encouraged to apply for an **AINSE Honours scholarship, Postgraduate Research Award (PGRA), or Residential Student Scholarship (RSS)**. Applications for the Honours scholarship open every December, while applications for the PGRA and RSS open every February and April, respectively. See the AINSE Website for further details.

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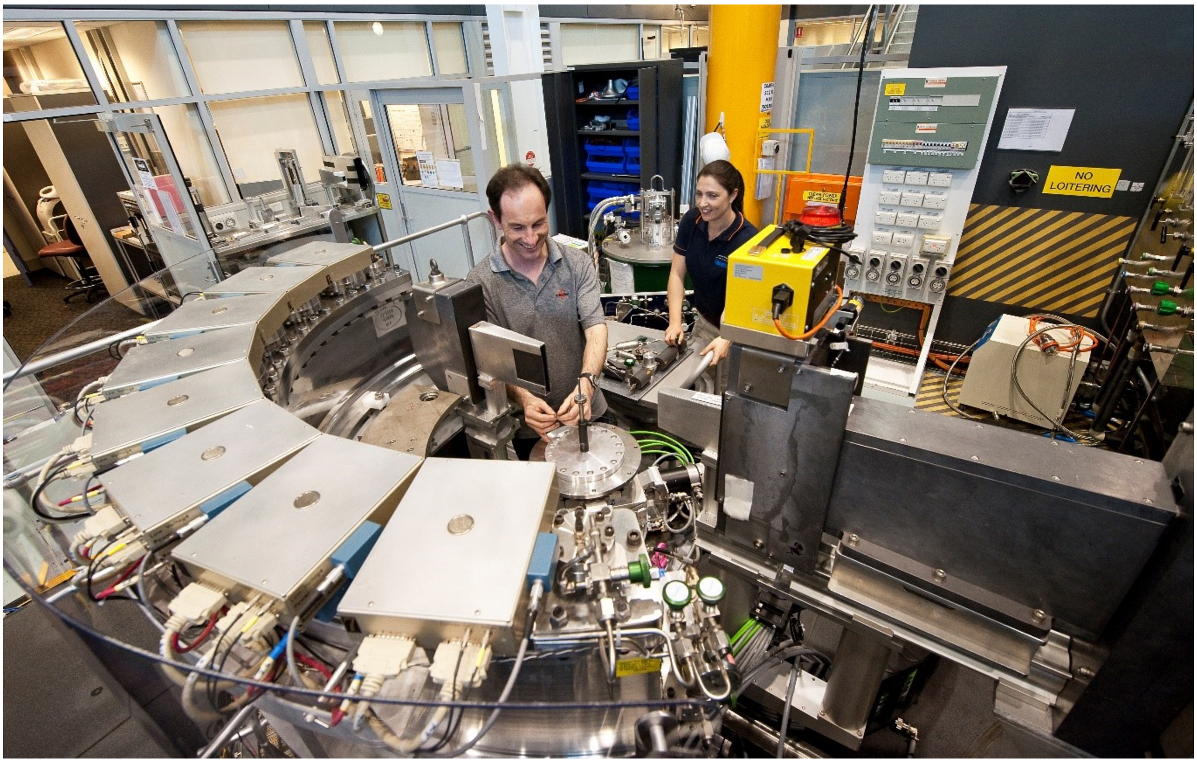
Contents (2/2)

Australian Centre for Neutron Scattering

The Australian Centre for Neutron Scattering (ACNS) is the home of neutron science in Australia and a leading facility in the Asia Oceania region.

ACNS comprises a suite of 15 neutron beam instruments classified into four main groups: diffractometers, small-angle spectrometers imaging and reflectometry instruments and inelastic spectrometers. These instruments offer a range of techniques applicable to scientific investigations across a broad spectrum of disciplines, including (but not limited to) physics, chemistry, materials science, medicine, cultural heritage, and environmental science.



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RESEARCH AREAS:

Quantum magnets

Investigating the dynamics of low dimensional quantum magnets: Linarite

Project Details

Fundamental research into low-dimensional and frustrated magnets has gained momentum recently due to advances in computational power and experimental measurement techniques. The combination of low dimensionality, frustration, and quantum physics effectively suppresses conventional long range order down to very low temperatures, which can lead to unconventional magnetic states such as quantum spin liquids [1], spin-Peierls states [2], and Tomonaga-Luttinger liquid phases. Additionally, when a magnetic field is applied to such systems, a range of exotic states such as spin-multipolar phases [3-5] may be induced.

We are currently investigating the exotic magnetic states in a range of low dimensional copper-oxide materials. By cooling the samples to very low temperatures and applying magnetic fields, we can examine the magnetic properties. Neutron scattering provides an excellent tool to directly probe the magnetic moments within a material and can tell us about both the magnetic structure and dynamics. From these measurements we can understand the interaction strengths and anisotropy and compare our data with mathematical models.

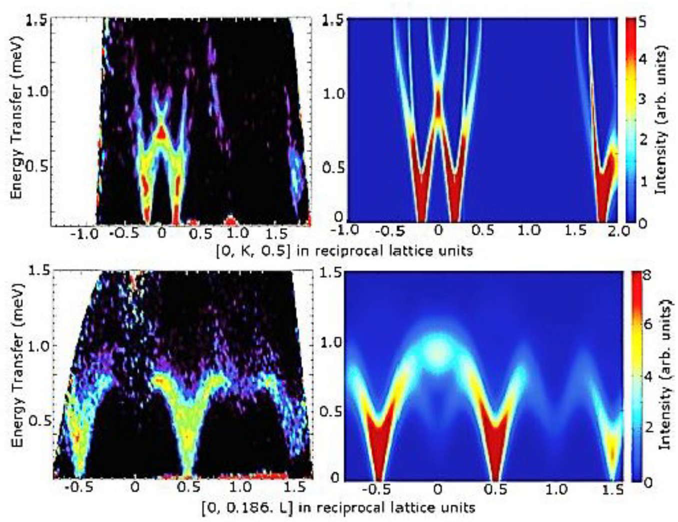

Fig 1. Inelastic neutron scattering data taken at CNCS at ORNL, USA. The top row shows the data (left) and model (right) collected along (0K0). The bottom row shows the data (left) and the model (right) for the data collected along (00L) [7]. Linear spin wave theory calculations modelled using Matlab package, SpinW.

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RESEARCH AREAS:

Quantum magnets

Linarite, PbCuSO4(OH)2 is a natural mineral which has been shown to display a rich and complex phase diagram in applied fields up to 10 T for temperatures below 2.8 K. As a frustrated J1-J2 chain material, linarite has recently been proposed as one of the best candidates for displaying a spin–nematic phase due to its accessible saturation field of 9.3 T [6]. Many researchers have been searching for such an experimental realization of this dynamic phase, which can be likened to the spontaneous alignment of rod-shaped molecules in Liquid Crystal Display (LCD) screens. Recent inelastic neutron scattering measurements in zero applied field (Fig. 1) have shown dispersive properties both parallel and perpendicular to the Cu-chains which have been successfully modelled with linear spin-wave theory [7]. Now we hope to extend this study to investigate the magnetic field dependence of the excitations, particularly close to saturation where we expect to see evidence of the elusive spin-nematic phase.

References:

[1] L. Balents, Nature (London) 464, 199 (2010).

[2] M. Arai, M. Fujita, M. Motokawa, J. Akimitsu, and S. M. Bennington, Phys. Rev. Lett. 77, 3649 (1996).

[3] A. V. Chubukov, Phys. Rev. B 44, 4693 (1991).

[4] T. Vekua, A. Honecker, H.-J. Mikeska, and F. Heidrich-Meisner, Phys. Rev. B 76, 174420 (2007).

[5] N. B¨uttgen, K. Nawa, T. Fujita, M. Hagiwara, P. Kuhns, A. Prokofiev, A. P. Reyes, L. E. Svistov, K. Yoshimura, and M. Takigawa, Phys. Rev. B 90, 134401 (2014).

[6] K.C. Rule et al., Physical Review Letters 100 117202 (2008); K.C. Rule et al., Physical Review B (2011).

[7] K.C. Rule et al., Phys. Rev. B 95, 024430 (2017).

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RESEARCH AREAS:

Quantum magnets

Investigating the dynamics of low dimensional quantum magnets: Atacamite

Project Details

Low dimensional magnetic materials often display a large range of novel magnetic behaviours due to the reduced number of magnetic interactions which they possess. In addition, low dimensional magnets formed from quantum spin systems (those magnetic ions with spin, $S < 1$, and zero-point spin fluctuations) and with frustrated topologies can exhibit new and exotic magnetic ground states, such as spin-liquid, spin-nematic and spin-Peirel states [1,2,3]. These materials have a potential application in the field of spintronics and magnonics as magnetic memories, microwave oscillators, modulators, sensors, logic gates, diodes and transistors.

We are currently investigating the exotic magnetic states in a range of low dimensional copper-oxide materials. By cooling the samples to very low temperatures and applying magnetic fields, we can ex-amine the magnetic properties. Neutron scattering provides an excellent tool to directly probe the magnetic moments within a material and can tell us about both the magnetic structure and dynamics. From these measurements we can understand the interaction strengths and anisotropy and compare our data with mathematical models.

Fig 1. Natural mineral crystals of Atacamite.

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RESEARCH AREAS:

Quantum magnets

One group of materials that we have begun to study are the polymorphs of Cu2Cl(OH)3, otherwise known as atacamite (Fig. 1) and clinoatacamite [4,5]. The question we hope to answer is what role does frustration play in the magnetic properties of these two structurally different, yet chemically identical materials? We plan to use a variety of techniques including elastic and inelastic neutron scattering as well as magnetisation and susceptibility measurements per-formed using the ANSTO physical property measurement system (PPMS). We also plan to conduct a detailed modelling of the exchange interactions using the Matlab package, SpinW (Fig. 2).

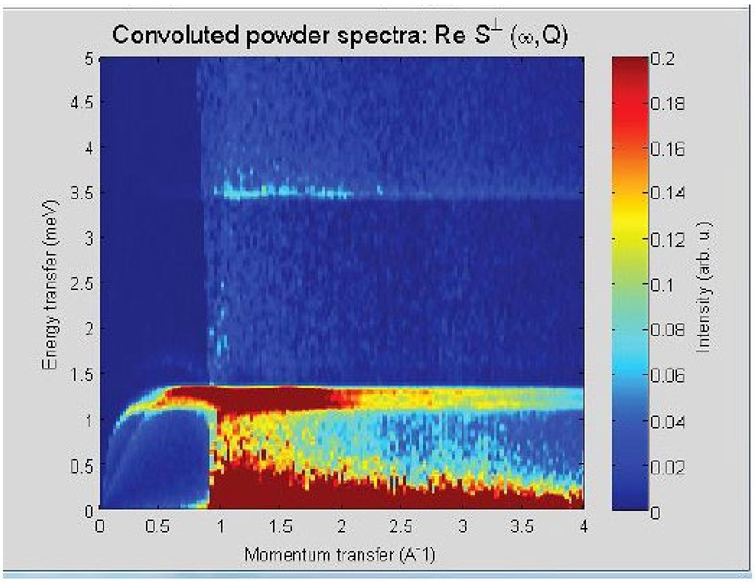

Fig 2. Preliminary spin wave theory calculations of the excitation spectrum of clinoatacamite.

References

[1] M. Arai, M. Fujita, M. Motokawa, J. Akimitsu, and S. M. Bennington, Phys. Rev. Lett. 77, 3649 (1996).

[2] A. V. Chubukov, Phys. Rev. B 44, 4693 (1991).

[3] L. Balents, Nature 464, 199 (2010).

[4] M. E. Fleet, Acta Crystallogr., Sect. B: Struct. Crystallogr. Cryst. Chem. 31 (1975) 183.

[5] X. G. Zheng, T. Mori, K. Nishiyama, W. Higemoto, H. Yamada, K. Nishikubo, C. N. Xu, Phys. Rev. B 71 (2005) 174404

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RESEARCH AREAS:

Food structure, polysaccharides, proteins, lipids, oleogels, soft matter

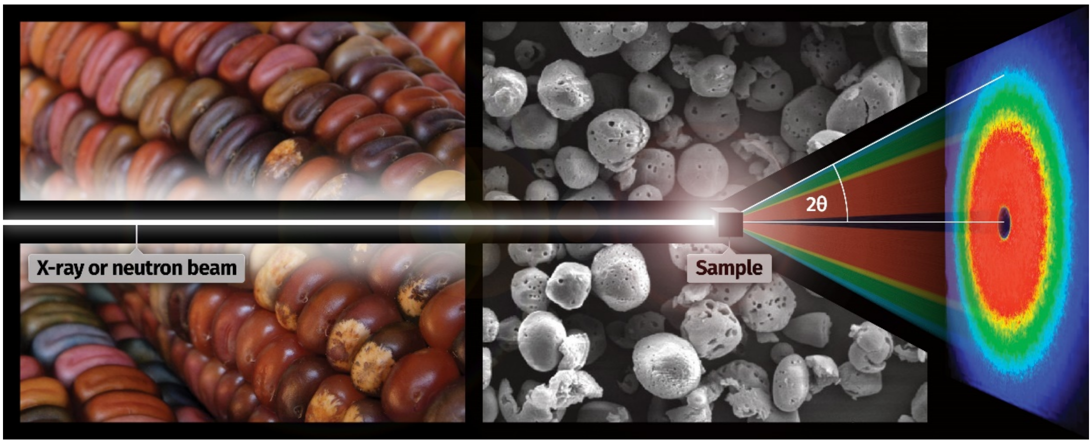
Food Materials

Project Details

The Food Materials Science Project draws on the disciplines of materials science and soft condensed matter physics and is underpinned by neutron scattering. Many of our investigations rely on the production of neutrons from the OPAL reactor to conduct studies using the technique of small-angle neutron scattering (SANS) at the instrument QUOKKA.

The SANS technique is ideal for the study of food since the available size range matches the dimensions of food ingredients such as carbohydrates, fats and proteins. In addition, SANS can enable enhanced information to be obtained by exploiting the neutron's isotopic sensitivity. This is done through a method known as 'contrast variation' which can distinguish components of different hydrogen content in a multi-component material.

Neutrons are not only useful for the determination of structure. The energy of a neutron can also be selected so that, after interacting with a material, its change in energy can be measured; this energy change can provide information on the translation, rotation or vibration of individual components. Consequently, quasielastic neutron scattering reveals valuable information on food components. Inevitably, when investigating industrial conditions, it is useful to observe what is occurring inside processing equipment. Due to their high penetration, neutrons can probe the structure of a material in operando during a process and neutron radiography also has a role to play in the food materials science project.



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RESEARCH AREAS:

Food structure, polysaccharides, proteins, lipids, oleogels, soft matter

The activities of the Food Materials Science Project can be broadly classified into three areas: (i) Food and Health, (ii) Food Processing and (iii) Food Structure-Function Relationships. Current systems under investigation include starch, cellulose, triglycerides, fatty acids and oleogelators. The project employs multiple characterisation techniques to complement small-angle neutron scattering including small-angle X-ray scattering, ultra-SANS, XRD, DSC and electron microscopy.

A variety of projects are available that can be tailored to the student's interests. Projects would be most suitable for students with a background in chemistry, physics, chemical engineering or materials science.

Australian Synchrotron

The Australian Synchrotron is one of Australia's most significant pieces of scientific infrastructure, used by more than 5,000 researchers each year.

The synchrotron produces powerful beams of X-ray and infrared radiation that is channelled down beamlines into a suite of scientific instruments. The types of instruments are broadly categorised by the way in which light is used: diffraction and scattering, spectroscopy, and imaging. There are currently 10 operational beamlines at the Australian Synchrotron with plans to expand the suite with an additional seven beamlines (under Project BRIGHT)

The advanced techniques available at the synchrotron are applied to research in many areas, including health and medical, food, environment, biotechnology, nanotechnology, energy, mining, agriculture, advanced materials, and cultural heritage.

High resolution chemical analysis of dairy and food products using synchrotron macro ATR-FTIR microspectroscopy

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RESEARCH AREAS:

Synchrotron, infrared, chemical analysis

Project Details

The project is focused on the application of high-resolution chemical imaging capability at Australian Synchrotron Infrared Microspectroscopy (IRM) Beamline, in the area of food science. Our in-house developed synchrotron macro ATR-FTIR microspectroscopic device (Fig. 1A) couples the synchrotron-IR beam to a germanium (Ge) hemispherical crystal, which effectively reduces the beam focus size and mapping step size by a factor of 4, leading to a significant improvement of the spatial resolution.

The synchrotron macro ATR-FTIR measurement at our beamline can be performed at minimum beam size of 1.9 µm, and at minimum mapping step size of 250 nm, allowing high-resolution chemical imaging analysis. The device can also be coupled to a temperature control unit (Fig. 1B), allowing temperature-dependent study, and measurements at a fixed temperature such as analysis of dairy products at 4°C to maintain its storage condition and freshness.

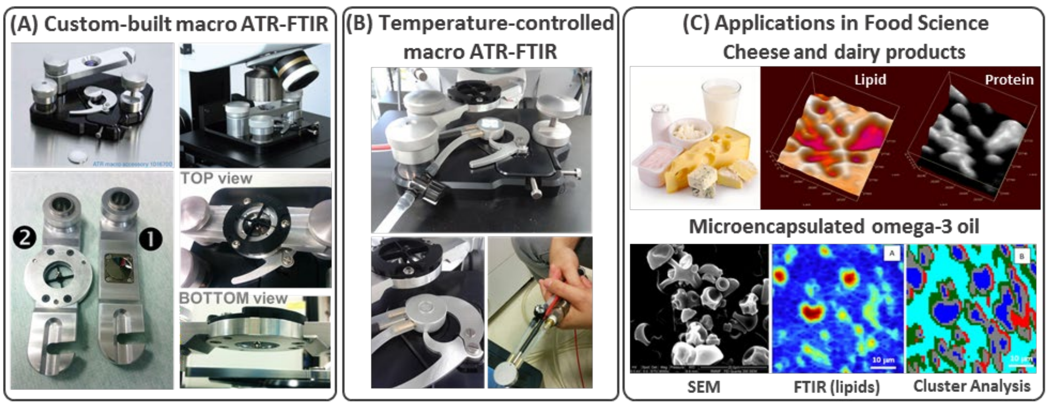

Figure 1: *(A) In-house developed macro ATR-FTIR device with different Ge crystal sizes, (B) when coupled with a temperature control unit, and (C) high-resolution synchrotron macro ATR-FTIR chemical images obtained from food products.*

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RESEARCH AREAS:

Synchrotron, infrared, chemical analysis

So far, the technique has demonstrated a strong potential for analysis of a range of food products [1-3]. In this project, we aim at using the technique to investigate a variety of dairy products (e.g. cheese and yoghurt) and food supplements (Fig. 1C) to support research and development of Australian food industries.

This interdisciplinary project could be of interest to students who have research interest in the areas of chemistry and food science. The student will learn to operate the in-house developed macro ATR-FTIR device, and will gain a good understanding of the op-tics used on the beamline and inside FTIR microscopes. Additionally, the student will be trained for comprehensive data analysis approaches, based on chemometrics, for analysing FTIR datasets of complex systems. The expertise gained from the project will provide the student advanced analytical skills to be able to tackle with the real-world research questions in both academic and industrial sectors.

References:

[1] YP Timilsena, J Vongsvivut, MJ Tobin, R Adhikari, C Barrow, B Adhikari, "Investigation of Lipid and Protein Distribution in Spray-Dried Chia Seed Oil Microcapsules Using Synchrotron-FTIR Microspectroscopy," ***Food Chemistry*, 275**, 457-466 (2019).

[2] AP Pax, L Ong, J Vongsvivut, MJ Tobin, SE Kentish, SL Gras, "The Characterisation of Mozzarella Cheese Microstructure Using High Resolution Synchrotron Transmission and ATR-FTIR Microspectroscopy," ***Food Chemistry*, 291**, 214-222 (2019).

[3] L Ong, AP Pax, A Ong, J Vongsvivut, MJ Tobin, SE Kentish, SL Gras, "Effects of pH on the Fat and Protein Aggregates within Cream Cheese and Their Influence on Textural and Rheological Properties," ***Food Chemistry*,** *in-press* (2020).

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RESEARCH AREAS:

Semiconducting polymers, organic electronics, soft matter, NEXAFS spectroscopy

NEXAFS Spectroscopy of Organic Electronic Thin Films

Project Details

In recent years a significant amount of research has been conducted in the development of next-generation flexible electronics such as for example solar cells and transistors based on semiconducting polymer thin films. It is well known that the morphology/microstructure of the solution processed active semiconducting polymer layer is important for the device performance. Near-Edge X-ray Absorption Fine-Structure (NEXAFS) spectroscopy is a unique tool that enables the probing of molecular orientation in extremely thin films. Additionally, NEXAFS spectroscopy can provide information about the electronic structure of semiconducting polymers.

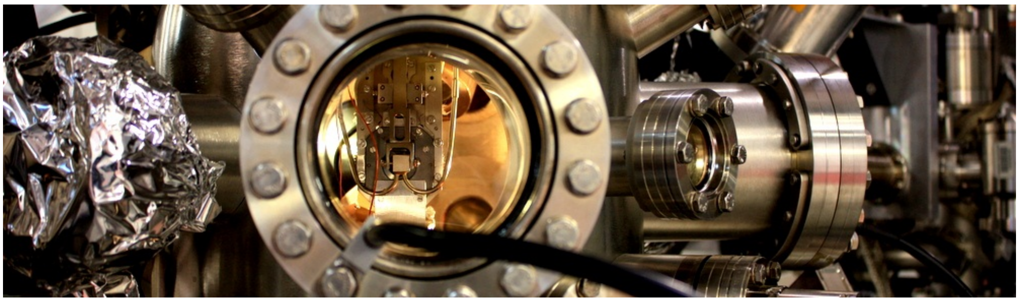

Photo of the end-station of the Soft X-ray beamline.

The intention behind this project is to join up with a group who specialise in fabrication and characterisation of organic electronic devices and to perform measurements of these thin film devices using NEXAFS spectroscopy at the Soft X-ray beamline at the Australian Synchrotron in order to gain a better understanding behind the morphology/microstructure versus device functionality. By studying thin films optimised for use in organic electronics, the project seeks to utilise NEXAFS spectroscopy to understand the link between film microstructure and electronic properties. This will be done by potentially answering questions such as:

• Will there be a difference between the orientation of polymer chains in the bulk compared to the interface?

• What understanding can we gain into the mechanisms of microstructure formation during solution deposition?

• When templating molecular orientation and alignment, what is the importance of the interface?

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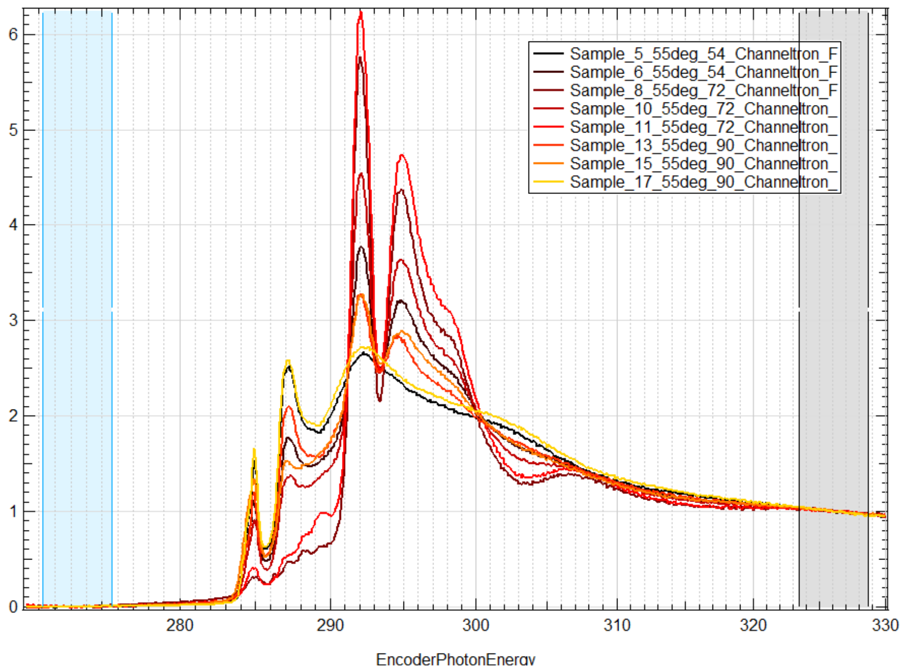
RESEARCH AREAS:

Semiconducting polymers, organic electronics, soft matter, NEXAFS spectroscopy

• What information can be extracted from NEXAFS spectroscopy regarding the electronic properties of semiconducting polymers?

The student is expected to spend some time at the Soft X-ray beamline at the Australian Synchrotron. This project would suit a high-achieving student with a background in Materials Science, Physics or Chemistry.



Evolution of NEXAFS spectra of a semiconducting polymer sample as a function changing sample preparation parameters.

Student Opportunities

- Learn the craft of synchrotron science at the Soft X-Ray (SXR) Beamline at the Australian Synchrotron.
- Get a deeper understanding of NEXAFS
- Be involved in commissioning periods at the SXR Beamline

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RESEARCH AREAS:

Machine Learning, Accelerator Physics, Particle Accelerators, Optimization

Particle Accelerators and Machine Learning

Project Details

Do you want to gain hands-on experience with the operation of a particle accelerator? Are you interested in using machine learning and analytical algorithms to solve real world problems?

Evolving from their modest origin as simple cathode ray tubes, modern day particle accelerators are complex machines with thousands of variables and subsystems, which often act at cross-purposes to one another.

Traditionally, we have relied on manual methods for data analysis and development of accelerator systems. However, accelerators are complex, with nonlinear phenomena and many interacting systems that make it hard to determine manually what the optimal solution for a design problem is or what the best machine operation settings are.

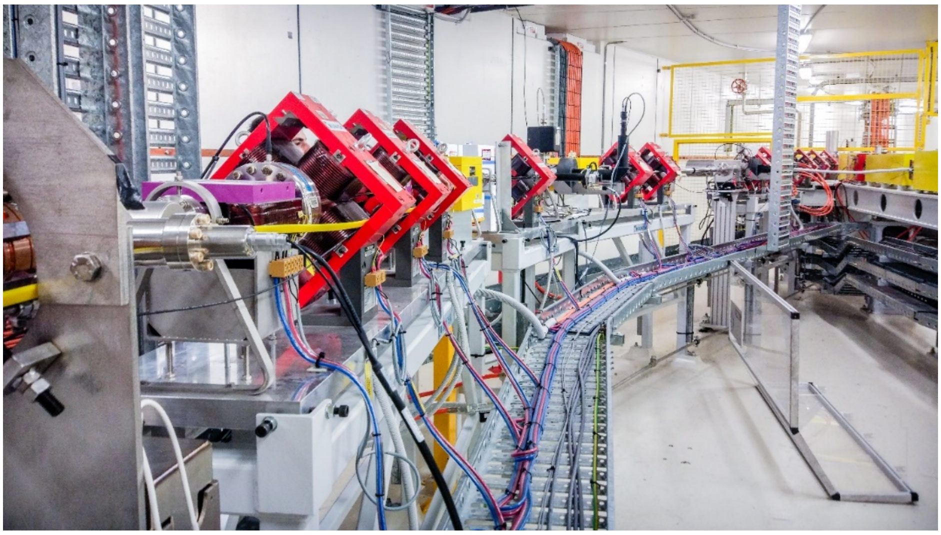

Figure 1: Magnets that guide the electron bunches around the 216 m Particle Accelerator at the Australian Synchrotron.

To overcome this limitation, we are looking for students to help our team continue to implement machine learning algorithms for the improvement and operation of our 3 GeV particle accelerator.

Previously, we have successfully used neural networks and online optimization algorithms for real-time accelerator control and design of accelerator systems. We are now looking to expand our efforts into other exciting areas. For example, you could help design the next generation accelerator facility or free electron laser in collaboration

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RESEARCH AREAS:

Machine Learning, Accelerator Physics, Particle Accelerators, Optimization

with our colleagues in Australia and internationally (Europe (CERN), America (SLAC), Japan (KEK)).

The student will gain hands-on experience with the operation of a 3 GeV particle accelerator. The student will work with a team of researchers in accelerator physics at the Australian Synchrotron and depending on the project, collaborate with our colleagues in Australia and internationally (Europe - CERN, America - SLAC, Japan - KEK).

Student Opportunities

Based on your interests, the project can progress in different ways. Potential projects include (but are not limited to!):

- We have a large amount of archived data that captures the machine state. You could explore trends & features to classify markers of each fault.
- You could also explore how to predict machine faults before beam is lost & trigger alarms to alert operators so they can intervene before the machine turns off.
- You could improve machine performance by using online tuning algorithms.
- You could use optimization algorithms to design an electron gun that needs to meet design constraints.

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RESEARCH AREAS:

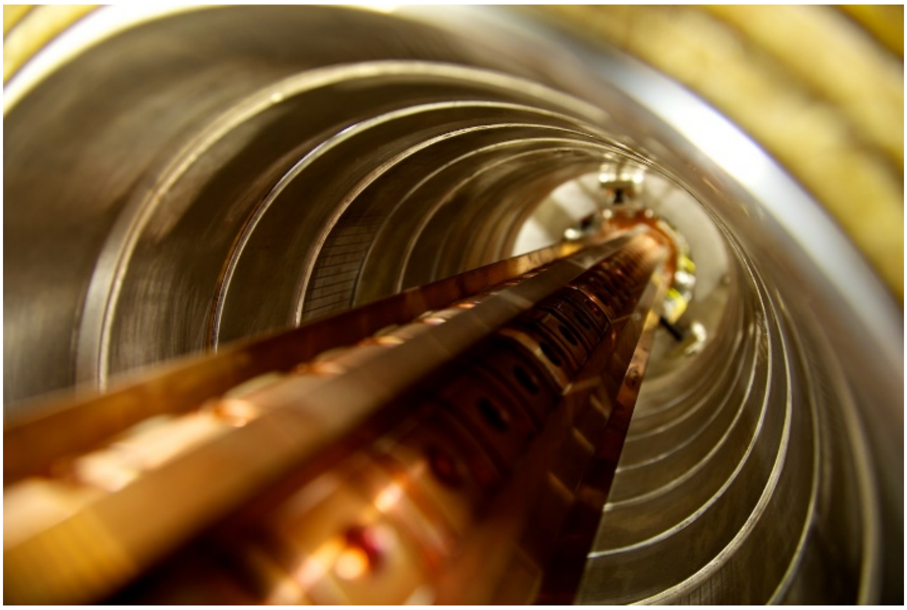
Physics, Mathematics, Computational Simulation

Electron Storage ring design studies

Project Details

The Accelerator Physics group at the Australian Synchrotron is currently designing a new, next generation synchrotron light source to meet Australia's future X-ray science infrastructure needs.

A conceptual design report for a new 600m, 3GeV electron storage ring is currently being developed, along with the associated linear accelerators. The design will incorporate the latest storage ring lattice techniques as well as compact acceleration technologies and will be used as the basis for Australia's next light source.



Australian Synchrotron 100 MeV Linear Accelerator

The new light source will seek to achieve a very competitive sub 50 pm radian beam emittance, giving it several orders of magnitude increase in brightness over the current Australian Synchrotron. It will incorporate a 3 GeV linear accelerator utilising compact X-band acceleration technology developed by CERN, a 4th generation multi-bend achromat lattice, and be able to host over 50 world class beamlines.

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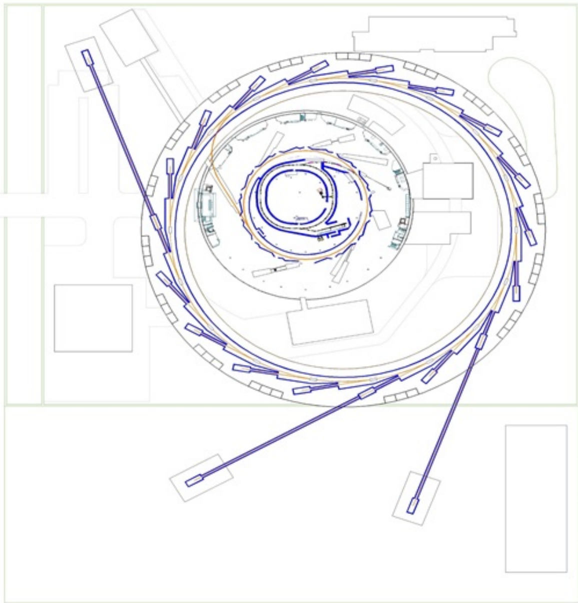
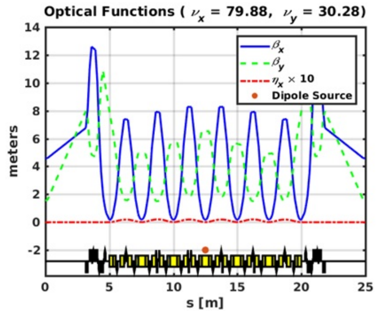
RESEARCH AREAS:

Physics, Mathematics, Computational Simulation



A possible layout of the next generation Australian synchrotron



Optics functions for one unit cell of proposed Multi Bend Achromat lattice for the Next Generation Australian Synchrotron

Student Opportunities

A student interested in this project will have the opportunity to work on a range of topics dependent on the students' interests. They will receive training and supervision in Accelerator Physics, with the opportunity to attend international accelerator schools and conferences throughout the project. They will also have the ability to use the Australian Synchrotron accelerator systems to train in accelerator operation and conduct feasibility studies and experiments in beam dynamics and instrumentation.

Possible topics include:

- Beam impedance and instabilities

- Beam injection schemes

- Compact linear accelerator design,

- Beam dynamics and particle tracking simulations

- Magnet design and lattice optimisation

- RF accelerating cavity design

- Electron Source design (either RF photocathode or laser-plasma source)

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RESEARCH AREAS:

Physics, Mathematics, Computational Simulation

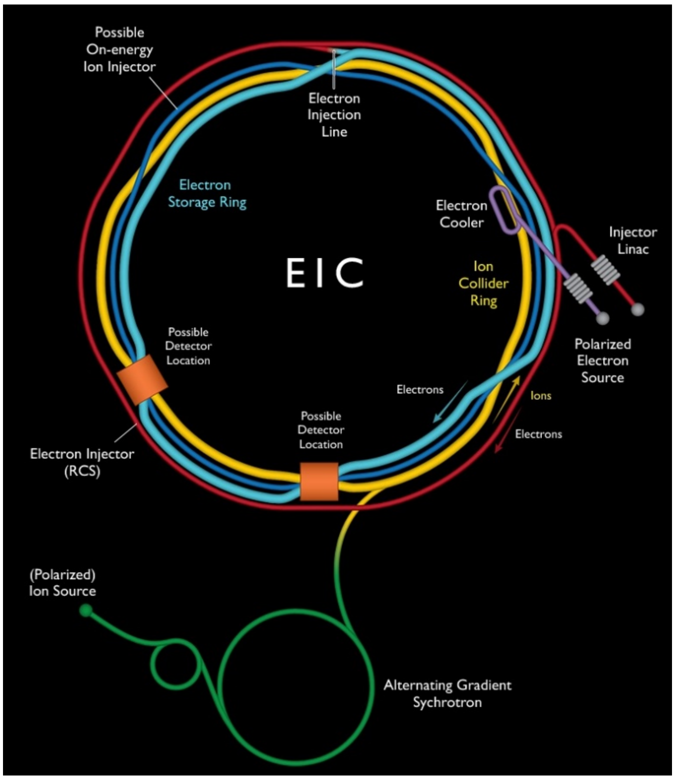
Design studies for the Electron Ion Collider

Project Details

All information technology --and much of our economy today --relies on understanding the electromagnetic force between the atomic nucleus and the electrons that orbit it.

The science of that force is well understood but we still know little about the microcosm within the protons and neutrons that make up the atomic nucleus. To explore this, Brookhaven Lab in the United States is building a new machine --an Electron-Ion Collider, or EIC --to look inside the nucleus and its protons and neutrons.

The EIC will be a particle accelerator that collides electrons with protons and nuclei to produce snapshots of those particles' internal structure. The electron beam will reveal the arrangement of the quarks and gluons that make up the protons and neutrons of nuclei. The force that holds quarks together, carried by the gluons, is the strongest force in Nature. The EIC will allow us to study this “strong nuclear force” and the role of gluons in the matter within and all around us. What we learn from the EIC could power the technologies of tomorrow.



Layout of the EIC accelerator systems

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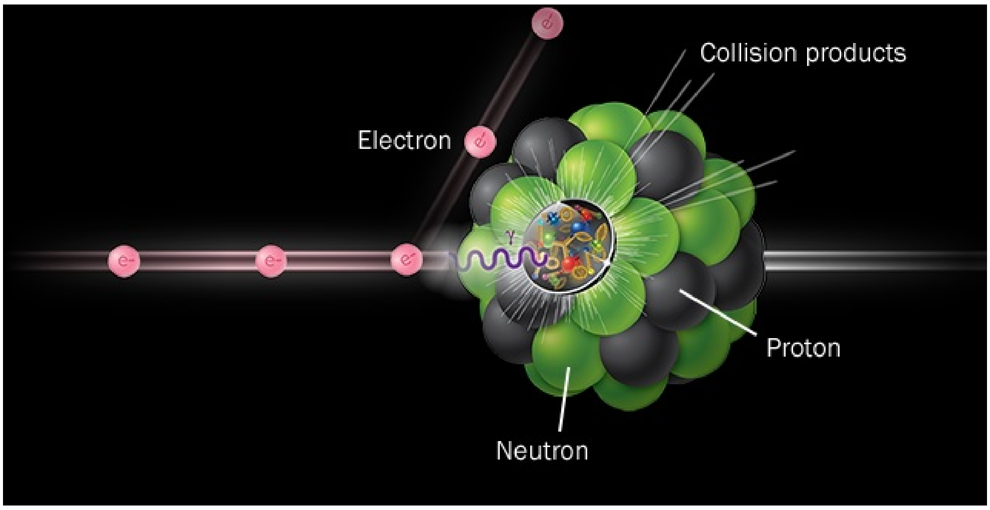
RESEARCH AREAS:

Physics, Mathematics, Computational Simulation

The EIC collaboration has been funded to move from conceptual design to technical design phase over the next few years, which will involve detailed design and development of the accelerators and associated systems. The EIC collaboration is actively inviting partners from around the world to collaborate and assist in this design effort and ANSTO has been invited to join. This projects offers you the opportunity to be part of the design of the next major international particle collider project and help explore the fundamental aspects of the strong Nuclear force.



Representation of an EIC collision

Student Opportunities

There are a range of options for topics to work on in this project and will be guided by the student's interests, our local expertise and the needs of the EIC collaboration. We will concentrate on the design of the electron storage ring of the EIC and possible topics include:

- Lattice design
- Magnet design
- Instrumentation and diagnostics
- Impedance evaluation and design of components.
- Beam stability and alignment tolerances.
- Beam Injection dynamics

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RESEARCH AREAS:

Physics, Particle Physics Simulations, Radiation dosimetry, Electronics

Dosimetry for VHEE Applications

Project Details

In 2020, 145 000 people are expected to be diagnosed with cancer in Australia alone. Developing new and effective treatment for the various forms of cancer is the subject of intense research. Recently FLASH radiotherapy with Very High Energy Electron (VHEE) beams has been proposed as an alternative to proton/hadron radiotherapy with the ability to penetrate deeply with little scattering due to the inertia of the electrons.

Research into quantifying the efficacy of this new modality is taking off around the world and one key problem that needs to be solved is to accurately measure the dose delivered in the FLASH regime, defined as a dose rate greater than 100 Gy/s. For VHEE beams typical dose rates are 10^6 Gy/s and it is unclear if current dosimeters, such as the MOSkin sensor, can still be used. The MOSkin sensor was developed by researchers at UOW's Centre for Medical Radiation Physics (CMRP) and is used in standard radiation therapy (X-rays) where dose rates are less than 100 Gy/s.

Figure 1: 100 MeV electron Linac (Left). Exposed radiographic film showing the distribution of the radiation at the end of the Linac which is measured with the two MOSkin sensors located behind the film.

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RESEARCH AREAS:

Physics, Particle Physics Simulations, Radiation dosimetry, Electronics

The Linac at the Australian Synchrotron is a prime candidate as a test source of VHEE beams and can deliver dose rates greater than 10^6 Gy/s. The project is to understand the distribution and spectral content of the radiation generated by the electrons from the Linac using a Monte Carlo particle simulator such as GEANT or FLUKA. The experimental component is to design and execute the experiment to investigate the response of the MOSkin radiation sensors in the FLASH regime using the Linac.

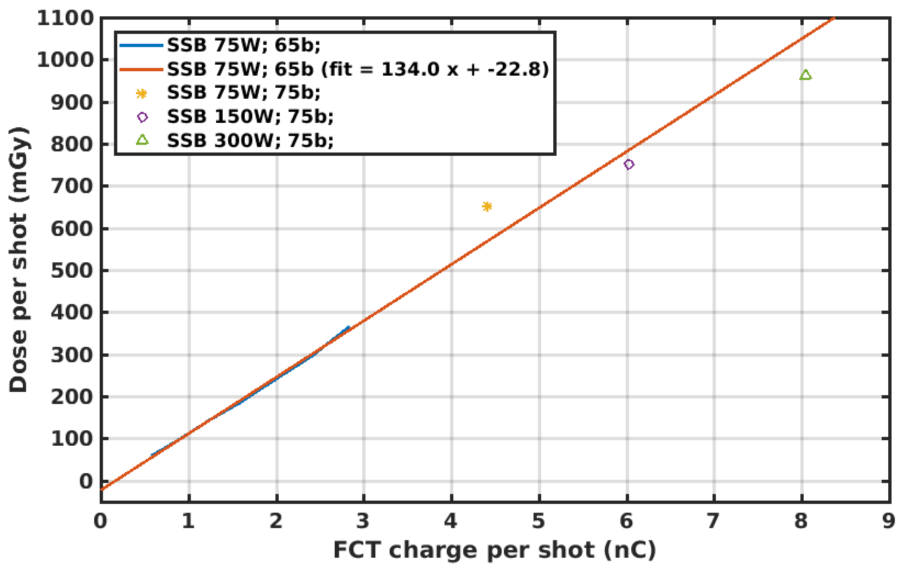

Figure 2: Measurements under 3 nC was an average of 20 measurements while above 3 nC is an average of 4 to 5 measurements with a longer bunch train. The total charge was calculated by integrating only the lead edge of the "step" in the dose measurement and eliminates the relaxation effect seen in some of the later measurements.

Student Opportunities

The student will have the opportunity to work with the operators/physicists to use the Linac at the Australian Synchrotron to design, build and conduct experiments to characterise the MOSkin radiation sensor. The student will also be developing a model of the Linac to calculate the radiation pattern using Monte Carlo particle simulators such as GEANT/FLUKA. The entire project will be done in collaboration with researchers at the University of Wollongong.

- Particle simulation with GEANT/FLUKA
- Use simulation data to calculate expected dose and dose rates
- Measure radiation dose from the 100 MeV electron Linac using the MOSkin sensor.
- Compare and analyse the simulation and measured data.

CONTACT:

Dr Keith Bambery

Australian Synchrotron

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RESEARCH AREAS:

Synchrotron materials analysis, Biology, Earth Science, Health Sciences, Python or MATLAB programming

Synchrotron Microscopy

Project Details

At the Australian Synchrotron, we have two beamlines dedicated to microscopy. Our X-ray Fluorescence Microscopy (XFM) beamline specialises in mapping the spatial distribution of most elements heavier than aluminium.

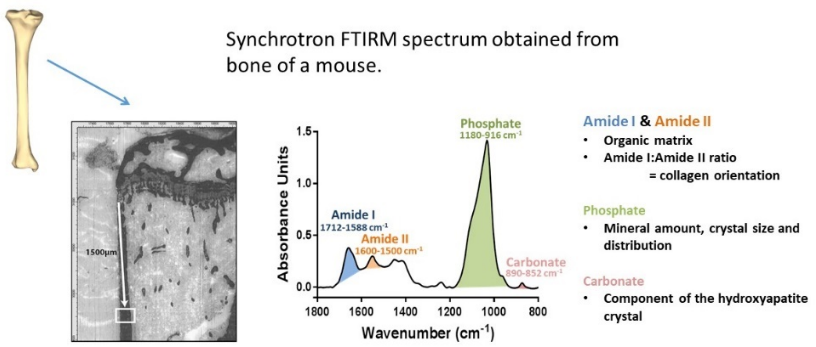
Our Infrared Microspectroscopy (IRM) beamline analyses chemical compositions in a broad range of samples from biology, medicine to archaeology and minerals. Both these beamlines are able to characterise the samples composition at scales of down to a few microns (2 - 10 micron) in hyperspectral imaging modes.

Dr Keith Bambery's research includes development of hyperspectral imaging and multivariate statistical analysis methods for synchrotron-based spectroscopy and microscopy applied to applications in materials science, cellular biochemistry, health and the environment.

Student Opportunities

Physical sciences students with existing research projects or with project ideas that could benefit from synchrotron-based approaches to microscopic characterization of samples are encouraged to suggest project ideas to Keith and the synchrotron's Microscopy Group Team. We welcome the opportunity to advise on ways that the synchrotron might be able to assist with your research questions.

Students with modelling, software development or computational research backgrounds might also be interested in projects we are working on in areas of data analysis for synchrotron microscopy including problems in multivariate statistics, machine learning, image processing and signal processing.



Christina Vrahnas et. al. Bone 93 2016 DOI: 10.1016/j.bone.2016.09.022

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A/Prof. Jack Clegg

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RESEARCH AREAS:

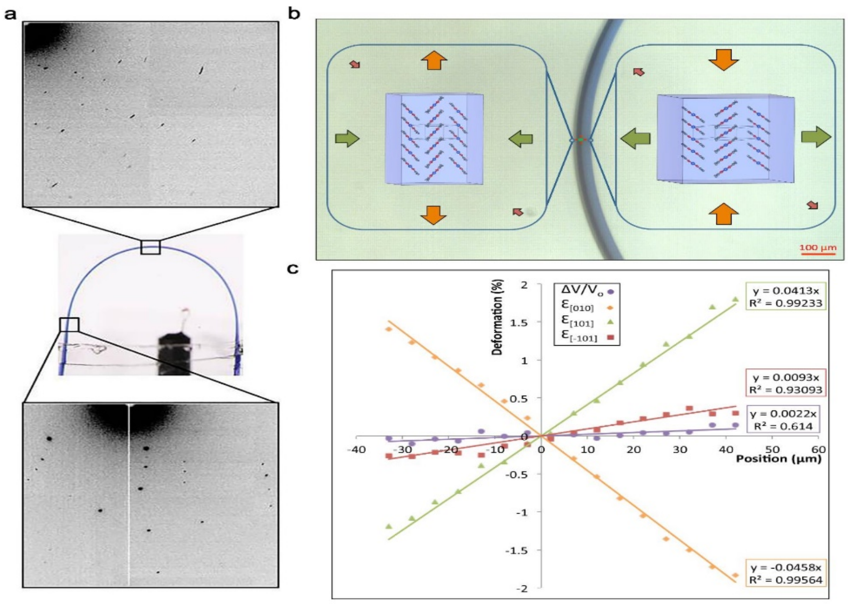
Synchrotron, Materials, Environment & Crystallography

*Stressed out crystals in synchrotron radiation

Project Details

The Flexible single crystals have many applications in flexible electronics including solar cells, where crystallinity may be a desired property[1-2]. Many organic and inorganic molecular single crystals are elastically flexible although they are poorly understood. By using the Australian Synchrotron micro-focus beamline (MX2)[3] we are able to investigate the profiles of individual crystals and understand the atomic-scale mechanisms that allow elastic flexibility in some crystals[4] but not in others. This new knowledge will allow the design of new functional materials.

We have recently identified a number of chemically distinct metal-organic crystals that display remarkable elastic flexibility. These are the first examples of flexible metal-organic crystals. They can be bent, stretched, compressed and twisted repeatedly without breaking or loss of single crystallinity. Some can even be contorted into loops and tied in simple knots.



The crystals so far identified defy the modern perceptions and understanding of crystalline solids. For example, a crystal that is bent or twisted, no longer retains simple linear periodicity between repeating molecular units. The anisotropy induced by contortion must, in turn, influence the optical, magnetic and electrical properties that arise from (or are enhanced by) the additive effects of periodicity. The presence of transition metal ions in these materials also provides access to other properties that arise from partially filled d-orbitals.

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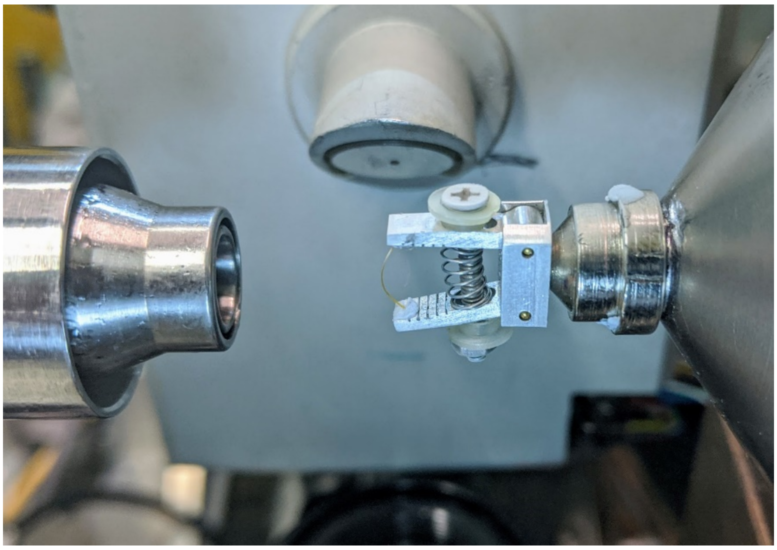
RESEARCH AREAS:

Synchrotron, Materials, Environment & Crystallography

While mechanical inflexibility typically limits the application of crystalline materials in new technologies such as flexible electronics, the discovery of a suite of metal-organic crystals that display appreciable elastic flexibility provides *entirely new opportunities* to employ single crystals in a wide range of technologies previously thought impossible.



This project involves the preparation of a new flexible crystals and mapping the structural changes using Synchrotron diffraction that occur during flexure.

The student will gain experience in the design and preparation of advanced materials along with cutting-edge Synchrotron and diffraction techniques.

References

1. D. W. Kang, J. Ryu and M. Konagai, *Electronic Materials Letters*, **2019**, 15 (5), 623-629.

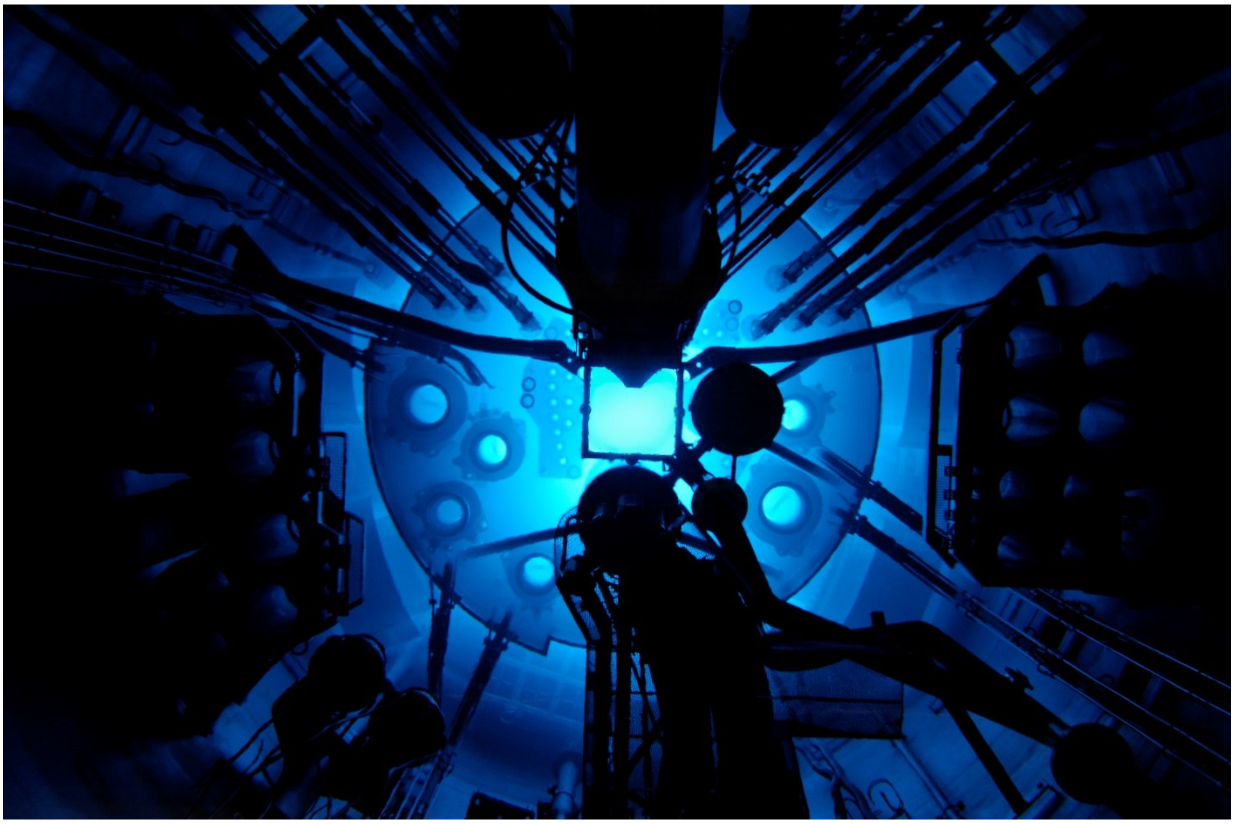
2. M. T. Zarmai, N. N. Ekere, C. F. Oduoza and E. H. Amalu, *Applied Energy,* **2015**, 154, 173-182.

3. D. Aragão, J. Aishima, H. Cherukuvada, R. Clarken, M. Clift, N. P. Cowieson, D. J. Ericsson, C. L. Gee, S. Macedo, N. Mudie, S. Pan-jikar, J. R. Price, A. Riboldi-Tunnicliffe, R. Rostan, R. Williamson and T. T. Caradoc-Davies, *Journal of Synchrotron Radiation*, **2018,** 25, 885-891.

4. A. Worthy, A. Grosjean, M. C. Pfrunder, Y. Xu, C. Yan, G. Edwards, J. K. Clegg and J. C. McMurtrie, *Nature Chemistry*, **2018**, 10(1), 65-69.

Nuclear Forensics and Nuclear Fuel Cycle

ANSTO is the home of Australia's nuclear expertise. As the operator of Australia's only nuclear reactor, ANSTO addresses key scientific questions in the nuclear fuel cycle for both the current generation of nuclear reactors and future systems. The nuclear fuel cycle begins with the mining of uranium and ends with the disposal of nuclear waste.



CONTACT:

Dr Jessica Veliscek Carolan

Nuclear Fuel Cycle

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RESEARCH AREAS:

Nuclear Fuel Cycle chemistry

Advanced Sorbent Materials for Actinide Separations

Project Details

Used nuclear fuel is currently considered waste in many countries, but it is possible to instead recycle parts of nuclear waste and use them again as fuel. The aim of this research is to develop novel materials that are able to selectively remove actinide elements such as uranium and americium from solutions of used nuclear fuel.

These actinide elements are targeted for separations because they can be recycled and because they are large contributors to the radiotoxicity and long lifetime of used nuclear fuel. In fact, if all the actinides could be removed from used nuclear fuel the remaining waste would take only 270 years to return to the radiotoxicity level of naturally occurring uranium, instead of 130,000 years (Figure 1). That's a pretty strong motivation to do these separations! Both in terms of environmental and human safety.

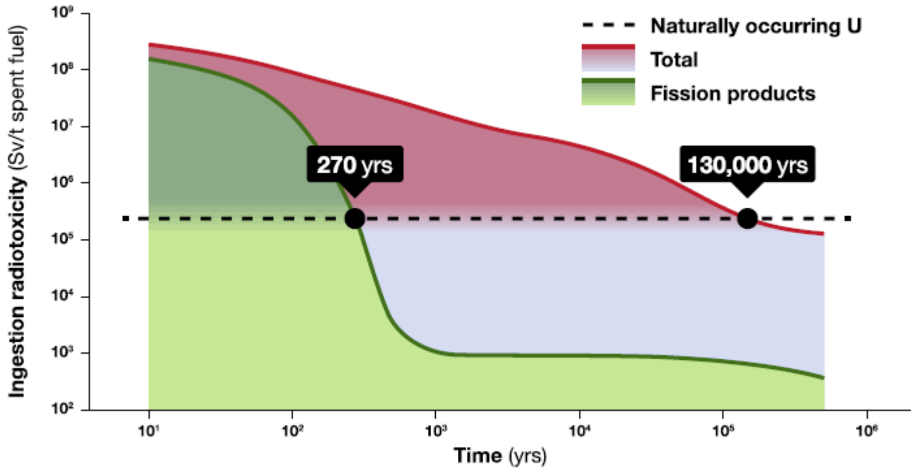

Figure 1: Radiotoxicity of used nuclear fuel ('nuclear waste') over time, with and without removal of actinides.

Sorbent materials for actinide separations need to be highly stable because they need to function in environments of high acidity and radiation. Therefore, sorbents based on the highly stable titania and zirconia are to be synthesized, like this titania bead shown in Figure 2. These materials also need to have an open, porous structure with high surface areas so they can absorb the maximum amount of actinides ('high capacity').

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RESEARCH AREAS:

Nuclear Fuel Cycle chemistry

Sorbent materials for actinide separations also need to be selective for the element to be separated, so that only that targeted element 'sticks' to the sorbent material but any other elements present pass straight through, as shown in Figure 3. To get this selectivity, organic functional groups need to be incorporated into the sorbent material. The type of organic functional group used will depend on the element targeted for separation.

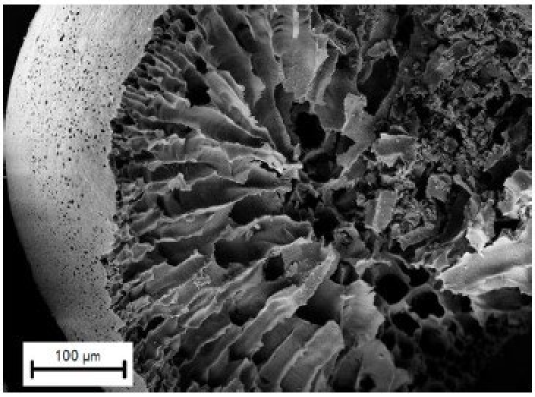

Figure 2: Scanning Electron Microscope (SEM) image of a titania bead.

To make and understand advanced sorbent materials for actinide separations, this project will involve both inorganic and organic synthesis, characterization using techniques such as x-ray diffraction (XRD), nuclear magnetic resonance (NMR) and electron microscopy, as well as testing the sorption performance of the materials synthesized.

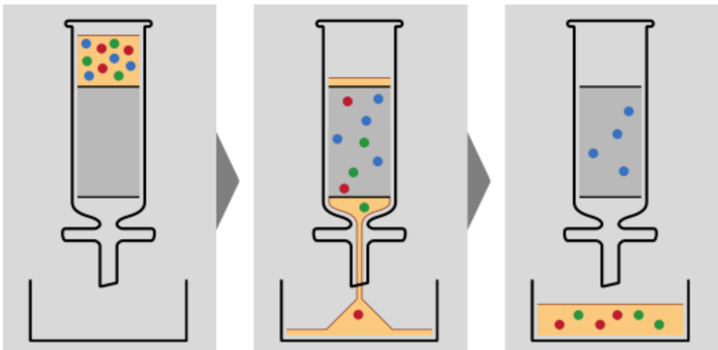

Figure 3: Schematic representation of selective separation using a solid phase sorbent material in a column.

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RESEARCH AREAS:

Nuclear Forensics, Analytical chemistry

Microscopic elemental, isotopic and chemical structure mapping of nuclear materials for nuclear forensics profiling

Project Details

Though nuclear and other radioactive material is tightly regulated and safeguarded, there have been reported cases of such materials being found out of regulatory control. The examination of nuclear or other radioactive materials in the context of legal proceedings or nuclear security is the subject of nuclear forensics. The goal of a nuclear forensic examination is to analyse unknown radioactive materials to obtain isotopic, chemical or physical data characteristics, or 'signatures', to identify what the materials are, how, when, and where the materials were made, and what were their intended uses.

Nuclear forensic signatures may be macroscopic physical characteristics (e.g. the size and shape of a nuclear fuel pellet), bulk signatures (e.g. elemental composition or U iso-topic ratios of a nuclear fuel pellet) or microscopic signatures (e.g. microscale variations in the spatial distribution of elemental, chemical or isotopic composition in a nuclear fuel pellet). This project will focus on development of techniques and processes for the characterisation of nuclear material on the microscopic level.

Unpacking a nuclear forensic sample in a glove bag

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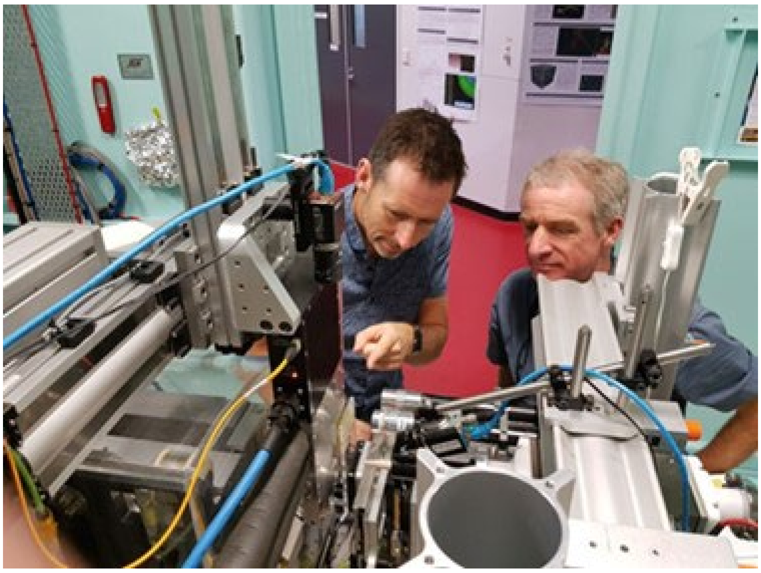
RESEARCH AREAS:

**Nuclear Forensics,
Analytical chemistry**

Microscopic signatures can be critical to a nuclear forensic investigation. In a number of both simulated and real nuclear forensic investigations ANSTO's nuclear forensic capability, along with other international nuclear forensic laboratories, have utilised microstructure signatures on bulk samples to answer crucial investigative questions such as determining whether duplicate samples from a mock seizure originated from the same facility [Taylor, F. et al, JRNC, 2020]. ANSTO has a committed research mandate to further develop such analytical capabilities and techniques to continue to support such international efforts.

ANSTO maintains a national nuclear forensics capability as part of Australia's international commitment to non-proliferation and nuclear security. The capability is constantly seeking to expand and improve analytical capabilities to respond to investigative questions from law enforcement following nuclear forensic incidents.

The project aims to use a selection of instruments from within ANSTO's landmark infrastructure to further develop the capability to map microscopic variations in elemental composition of nuclear material with chemical structure analysis at the microscale. This information can be utilised to help identify the type, history and origin of the nuclear materials under investigation. The project may include development of protocols for sample preparation, staging for analysis, analytical measurement, and data interpretation for analysis of radioactive samples on a range of instruments such as the Australian synchrotron X-ray fluorescence (XRF) beam-line, scanning electron microscopy - energy dispersive X-ray spectroscopy (SEM-EDX), Centre for Accelerator Science micro-particle induced X-ray emission (PIXE) and accelerator mass spectrometry (AMS).



Loading a sample for Synchrotron XFM analysis

The project may also seek to compare the performance and benefits of microanalysis techniques with complimentary or competing analytical

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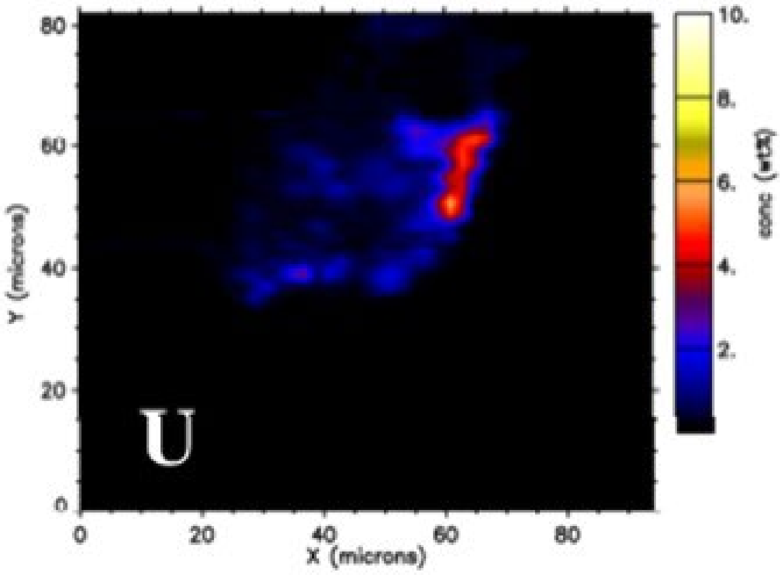
RESEARCH AREAS:

Nuclear Forensics, Analytical chemistry

capabilities in order to develop a clear hierarchy of response during a nuclear forensic examination. For instance, comparison of the accelerator based micro-elemental mapping techniques of PIXE, PIGE and RBS with scanning electron microscopy based techniques such as SEM-EDX and focussed ion beam (FIB). The project may also develop techniques to discern additional information on composition and manufacturing history of nuclear materials, such as measurement of microscopic spatial variability of isotopic ratios of uranium and plutonium. Of particular interest is the potential of FIB-SEM based time of flight secondary ion mass spectrometer (ToF-SIMS) for isotopic and elemental analysis and for depth profiling to enable examination of surface modifications.



Synchrotron X-ray fluorescence microscopy (SXFM) results of a radioactive particle showing U distribution

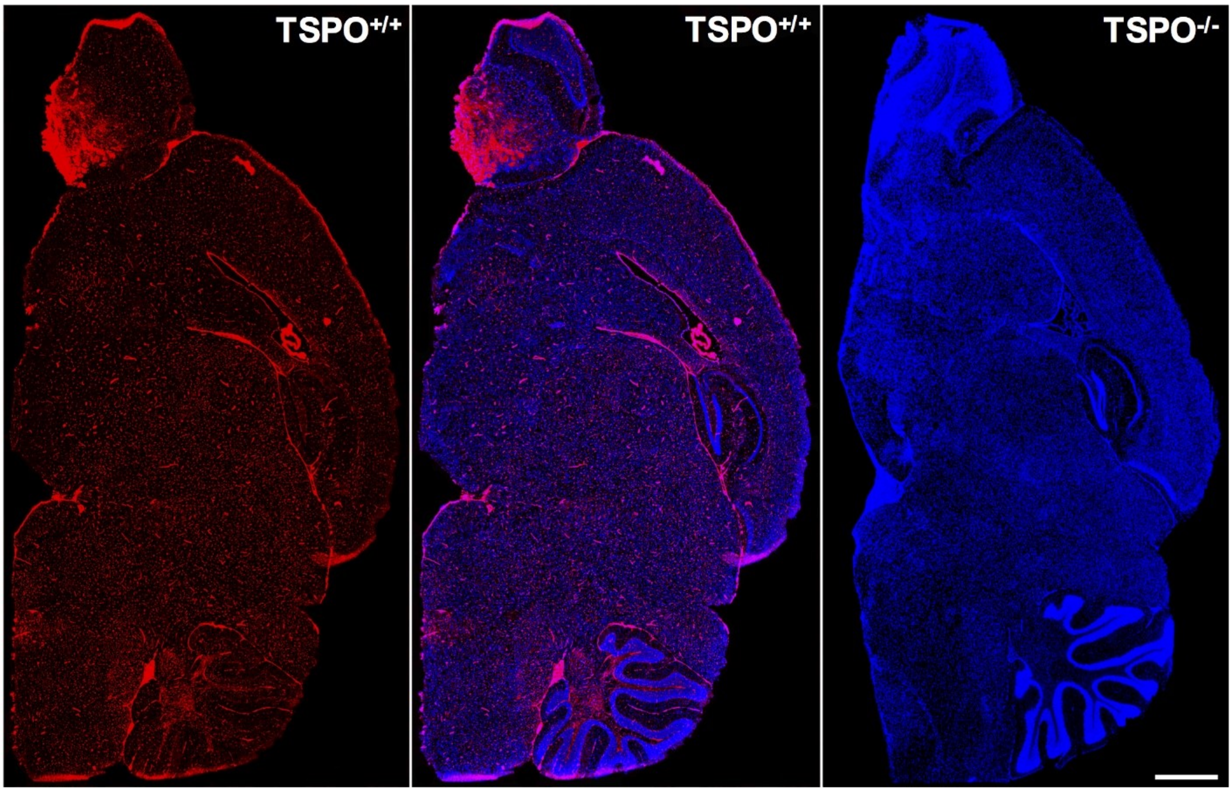
This project is an opportunity to gain technical familiarity with microanalysis techniques available at ANSTO. The student will select a technique/s from the following to examine nuclear forensic samples:

- Centre for Accelerator Science ion beam analysis (particle-induced X-ray emission (PIXE), Rutherford backscattering spectrometry (RBS), particle-induced gamma emission (PIGE))
- Scanning electron microscopy - energy dispersive X-ray (SEM-EDX) spectroscopy
- Focused ion beam SEM based time of flight secondary ion mass spectrometry (FIB-ToF-SIMS)
- FIB-SEM
- Synchrotron techniques, particularly synchrotron X-ray fluorescence (XRF)

The student will also develop collaborative contacts with beamline scientists, instrument operators and research scientists in the Nuclear Forensics capability.

Health

ANSTO uses its infrastructure, capabilities and expertise to build knowledge and optimise the beneficial impacts of nuclear science on human health; produce current and future nuclear medicine; and enables research into prevention and approaches to improve the detection, diagnosis and treatment of disease.



CONTACT:

A/Prof. Guo-Jun Liu

ANSTO LifeSciences

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RESEARCH AREAS:

Human health, Radiation

Role of mitochondrial protein in radiation and neuroinflammation

Project Details

Our research focuses on mitochondrial proteins that have a variety of potential functions in both health and disease, notably during the activation of microglia, the brain's resident immune effector cell. We are currently investigating the function, structure, ligand binding response and distribution of a protein that regulates energy production in mitochondria.

This is highlighted by our recent work on the generation and characterisation of mice that lack the mitochondrial 18 kDa translocator protein/peripheral benzodiazepine receptor (TSPO/PBR; Banati et al., Nature Communications, 2014).

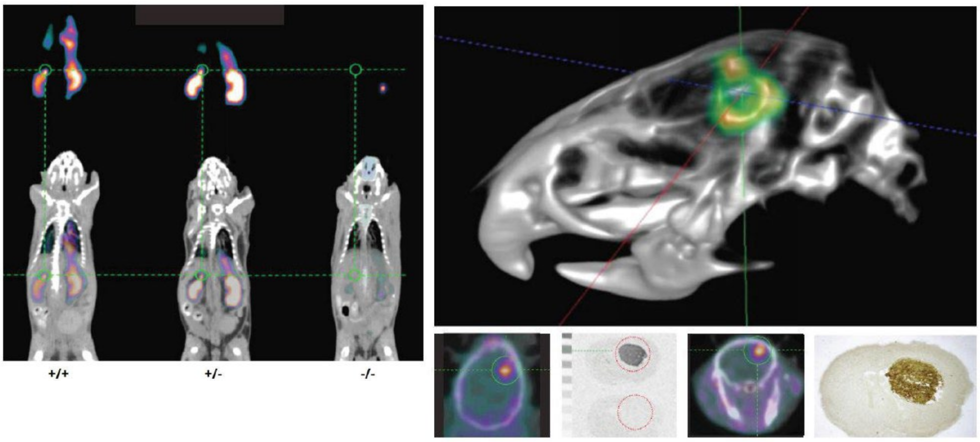
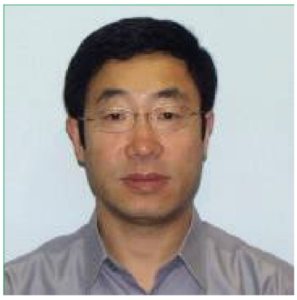


Fig 1. Non-TSPO transgenic mice are useful models for evaluating radiotracers with PET imaging to monitor the progress of brain tumours. Left is the normal PET imaging with [^{18}F]PBR111 and right is the brain tumour cells (TSPO+/+) injected into the non-TSPO (TSPO-/-) mice.

For this project, we are particularly interested in the impact of radiation on mitochondria and role of this protein in neuroinflammation including Alzheimer's Disease, multiple sclerosis and neuronal injury. The project involves the measurement of mitochondrial protein expression and its correlation with neuronal and glial proteins (markers) in normal and transgenic mice. The techniques used will include cryo-sectioning of tissue, histology, immunohistochemistry, immunofluorescence, autoradiography, and radioligand binding assays.



CONTACT:

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RESEARCH AREAS:

Human health, Radiation

A background in medical sciences, or biology, or neuroscience and/or pharmacology is desirable, but the necessary technical skills will be acquired during the project.

Researcher Bio

Dr Guo-Jun Liu is the Biology Group Leader at the Australian Nuclear Science and Technology Organisation (ANSTO). He holds an adjunct associate professorship at the University of Sydney.

His main area of research is in neuroscience, focusing on the roles of mitochondrial protein 18 kDa translocator protein (TSPO) in response to radiation. The areas of his expertise include radiobiology, immune-biology, cell biology, electrophysiology, and animal behaviour.

He began his scientific research career after he received an MD and masters in neurophysiology from the Jilin University in China, where he worked as Assistant Professor. After he received his PhD in Neurosciences from the Gifu University, School of Medicine in Japan, he was awarded an university Postdoctoral Fellowship by the University of Western Australia and then an university Fellowship by the University of Technology Sydney . As then senior research fellow, he continued his research in neuroscience in the Department of Physiology, Brain and Mind Centre at the University of Sydney.

References

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2. Liu GJ , Middleton RJ, Hatty CR, Kam WWY, Chan R, Pham T, Harrison-Brown M, Dodson E, Veale K and Banati RB, (2014) The 18 kDa translocator protein, microglia and neuroinflammation. Brain Pathology, 24:631-653.

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Advanced Imaging of Fracture Healing

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RESEARCH AREAS:

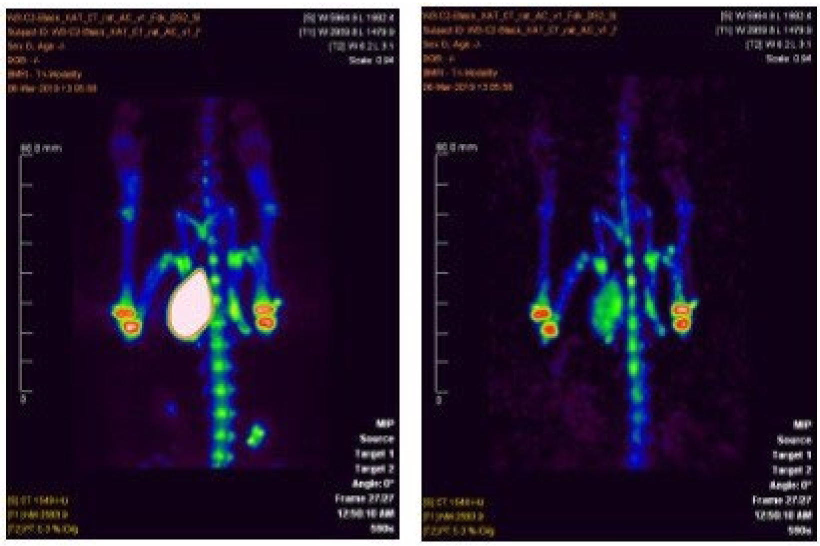
Imaging, PET/CT, SPECT/CT, multimodality imaging, fractures, medical science

Project Details

Over the last 20 years, radioimaging using either PET or SPECT scanner has been used to assist clinicians as their diagnostic tools. While both scanners have their own benefits, they also have their own limitations such as the different radiotracers that can be used, the quality of the images as well as the cost of the scanner and radio-tracers.

In the last 8 years, manufacturers have started creating multi-modality systems which encompass PET, SPECT and CT scanners (Guerra and Belcari, 2014). One of these systems is the Siemens Inveon, which ANSTO accrued as part of the contribution to National Imaging Facility (NIF) project. This system has been used extensively in our projects (internal and external). However, to date, we have only utilized the PET scanner or SPECT scanner individually, never in conjunction with one another.

While the system does not allow simultaneous measurement, it can perform sequential measurements between PET, SPECT and CT. This will enable us to evaluate the distribution of different radiotracers within the same subject. Furthermore, using this method, we can increase time efficiency and reduce the number of anaesthesia a subject is objected to. Currently there are only limited number of studies looking into the dual-tracer measurements using SPECT and PET scanner (Chapman et al, 2012).



Different radioisotopes and different modalities within the scanner

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RESEARCH AREAS:

Imaging, PET/CT, SPECT/CT, multimodality imaging, fractures, medical science

In this research project, we are planning to evaluate the possibility and limitations of dual-radiotracer imaging of PET and SPECT using our system in a well-known small animal fracture model. Upon the completion of this project we will be able to confidently use this method in our future experiments hence increasing our facility capabilities and will also be able to offer this service to our clients and collaborators.

In this study the student will be involved in the scanning/imaging process and data analysis. The student will be introduced to the different radioisotopes used for the project, the animal model used and the multimodality functions of the scanner (PET, SPECT and CT). The student will also receive training and experience in the imaging data processing and analysis.

CONTACT:

A/Prof. Ben Fraser

Radiotracer Methods and Organic Chemistry

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Podcast: link

RESEARCH AREAS:

Chemistry, Medicinal Chemistry, Biology

Radiopharmaceuticals and Agents for Cancer Diagnosis and Treatment

Project Details

NCEPT is a radical new approach to particle therapy being pioneered at ANSTO and other University partners. The technology works by delivering a "one-two punch" to cancer cells. The first punch is given by the particle beam through direct irradiation of the tumour cells, while the second punch is given by agents which capture by-product thermal neutrons generated during the irradiation. The secondary neutron capture events release high energy particles such as lithium ions, helium ions or Auger electrons which further damage and kill cancer cells.

The ANSTO NCEPT program is lead by Dr Mitra Safavi-Naeini and the NCEPT chemistry program by A/Prof. Benjamin Fraser. See the ANSTO video linked here for a detailed description of NCEPT by our project leader Dr. Mitra Safavi-Naeini.

A PhD project on the development of new agents for NCEPT will focus on classes of cancer where particle therapy is currently used and where NCEPT is anticipated to have significant benefit to patients. This includes melanoma, pancreatic cancer, head and neck cancer and several classes of brain tumours. The PhD project will have the following stages;

Stage 1 - Organic synthesis: A small library of compounds based upon a lead compound will be synthesised and chemically characterised. The compounds will contain the neutron capture isotopes boron-10 and/or gadolinium-157.

Stage 2 - In vitro screening: The library of compounds will be screened for their ability to interact with biological targets (enzyme binding, transporter affinity etc) and their ability to be taken up by cancer cells.

Stage 3 – Radiolabelling: Selected analogues from the library (based upon in vitro results) will be radiolabeled for co-development as companion treatment planning tools.

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Radiotracer Methods and Organic Chemistry

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Podcast: link

RESEARCH AREAS:

Chemistry, Medicinal Chemistry, Biology

Stage 4 – In vivo screening: Promising compounds from the in vitro screening and radiolabelling studies may be evaluated in animal models of cancer including rat and mouse tumour xenograft models.

Researcher Bio

A/Prof. Benjamin Fraser has over fifteen years of experience in organic chemistry and radiochemistry and leads the organic chemistry capability in ANSTO Biosciences and manages the Radiotherapy and Theranostics Research Program.

Ben's main research interests are (1) synthesis, radiolabeling and evaluation of small molecules, peptides and other biological vectors as potential new radiopharmaceuticals. (2) The development of new methods (faster, higher yielding, operationally straight-forward) for radiolabeling small molecules, peptides and other biological vectors with the SPECT and PET radioisotopes. (3) Labeling of radiotracers with deuterium to improve in vivo characteristics (NDF collaboration). Synthesis of small compound libraries for evaluation as both medical imaging agents and regular pharmaceutical therapeutics. Radiotracer / radiopharmaceutical development targeting diseases including Depression, Alzheimer’s and Multiple Sclerosis.

Ben has collaborative projects with Harvard Medical School (Boston, US), The National Deuteration Facility (NDF), Memorial Sloan-Kettering Cancer Centre (New York, US), The University of Texas (San Antonio, US), Curtin University (Perth, Australia) and Monash University (Melbourne, Australia). Ben continues his passion for teaching and education through lecturing on radiopharmaceuticals at Monash University (Melbourne), Curtin University (Perth) and The University of New South Wales (Sydney).

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Nuclear Materials Development and Characterisation

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RESEARCH AREAS:

Biology: Pharmacology, toxicology. Physical sciences: radioisotope chemistry, materials science, neutron/X-ray scattering and synchrotron imaging (x ray fluorescence, infrared spectroscopy)

Bioavailability of titanium dioxide nanoparticles used in food

Project Details

Innovation through nanotechnology is a growth opportunity for Australia's agri-food industry but has been limited due, in large part, to consumer resistance based on safety concerns.

Although nano-sized particles are present naturally in the environment and in some foods, a typical concern of consumer groups is whether insoluble engineered nanoparticles added to food products behave differently in the body compared to larger particles that have been traditionally used in food processing. For example, titanium dioxide (TiO2) has a history of safe use as a whitening agent, but the increasing use of nano-sized TiO2 particles has raised the question of whether they have different physicochemical properties following ingestion compared to traditional food-grade TiO2. The question of whether nano-sized TiO2 has a different fate and behaviour in humans following ingestion, compared to food-grade TiO2 can be extended to other agents and remains of great regulatory and consumer interest.

There is currently a need to refine and standardise methodologies for understanding the pharmacokinetics of insoluble nanoparticles in animal models. In this space we uniquely combine methodologies in materials science, pharmacology and nuclear sciences to be able to understand how nanoparticles are taken up into different organs of the body after oral administration, and further understand what they do in those locations (in terms of health benefits, or potential unwanted effects).

This project brings together two national research agencies (ANSTO, National Measurement Institute-NMI) and a university partner (University of Western Australia/Sir Charles Gairdner Hospital) to label TiO2 nano and food-grade particles with vanadium 48 (48V-TiO2) to allow the very sensitive measurement of concentration in vivo, as well as the ability to track their fate over time.

Research opportunities exist for students with biological and/or physical science backgrounds, in the fields of pharmacology/toxicology, radioisotope chemistry, materials science, neutron/X-ray scattering and synchrotron imaging. Please contact the coordinator (Paul Callaghan) in the first instance.

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ANSTO Human Health

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RESEARCH AREAS:

Biology: Pharmacology, toxicology, Neuroscience

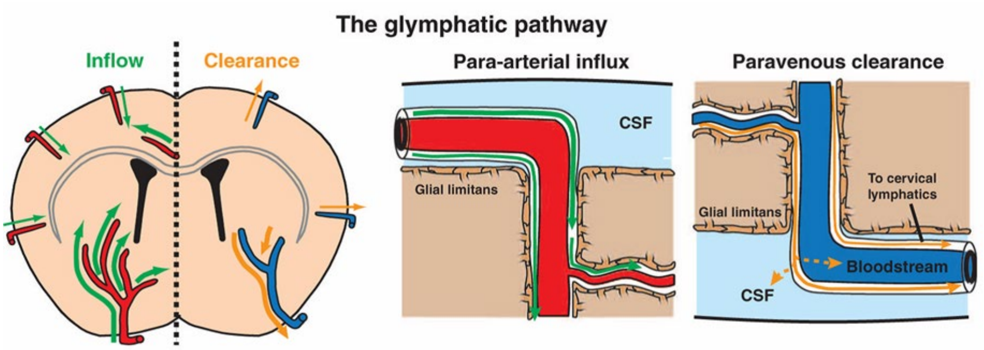
Radiation impact on glymphatic function within brain

Project Details

The brain tissue microenvironment is protected from unwanted metabolic products, drugs and proteins by the blood brain barrier, an endothelial structure within these blood vessels.

The lymphatic system is a vascular and tissue network within all parts of the body, except the brain, that transports lymph, a clear plasma-like fluid, that clears waste products from tissue and is enriched in immune cells, to fight pathogens.

The glymphatic system is a recently discovered perivascular network situated within the blood brain barrier that fulfils the role of the lymphatic system inside the blood-brain barrier (see figure, from 2), namely clearance of metabolic products and soluble proteins from the extracellular space and cerebrospinal fluid (CSF; 1,2). Anatomically, it consists of a network of perivascular channels made by the feet of astrocytes (glia limitans) alongside major and minor vasculature (arterial, venous and capillary beds).



The full extent to which this system modulates convective flow of CSF in health and disease is an active research field. We aim to implement nuclear science and technology approaches to characterise the dynamics of CSF flow and waste product efflux within the brain in health and disease, using radiotracers and subsequently positron emission tomography (PET). Understanding the role of the glymphatic system plays in modulation of therapies for treating brain tumors, through modulation of cytotoxic drug influx and efflux within the brain is a key focus.

CONTACT:

Dr Paul Callaghan

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RESEARCH AREAS:

Biology: Pharmacology, toxicology, Neuroscience

Research opportunities exist for students in biological fields of neuroscience, pharmacology and/or toxicology.

References:

1. Jessen, N.A., et al., 2015. The Glymphatic System: A Beginner's Guide. Neurochem Res. 40, 2583-99.

2. Iliff, J.J., et al., 2012. A paravascular pathway facilitates CSF flow through the brain parenchyma and the clearance of interstitial solutes, including amyloid beta. Sci Transl Med. 4, 147ra111.

CONTACT:

Dr Rob Russell

National Deuteration Facility (NDF)

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YouTube: [Link]

RESEARCH AREAS:

Biochemistry, biotechnology

Biosynthesis of deuterated lipids for medical and biotech research

Project Details

The National Deuteration Facilty (NDF) is focused on providing a range of deuterated molecules to our collaborators. We produce these deuterated molecules via chemical synthesis or microbial biosynthesis.

The hydrothermal catalysis of fatty acids produces a variety of deuterated fatty acids, which can be used for synthesis of a range of neutral and polar lipids. More recently we have used yeast platforms for the biosynthesis of deuterated sterols and lipids.

Deuteration of cholesterol is required to study the structure of lipid membranes, and has recently been used to characterise lipid nanoparticles for mRNA vaccine development. The combination of deuteration and neutron scattering analysis is also used in the study of viral interaction with cell membranes.

The NDF is keen to expand the range of deuterated molecules that can be used in medical, health and food research projects. We currently produce gram-scale quantities of the unsaturated hydrocarbon squalene, which is a precursor for steroids in animals and plants. It is currently used as an important ingredient in the cosmetic industry because of its effectiveness as a singlet oxygen quencher. Deuterated lipids, fatty acids and phospholipids present exciting opportunities for development of new therapies and products.

Student Opportunities

The NDF can support research projects where the use of isotope-labelled molecules can be used for characterisation (small angle neutron scattering, Infrared microscopy, NMR), or where the functionality of a material can be improved through deuteration.

We have the infrastructure for the chemical or biological synthesis of deuterated molecules, including the purification and analysis of products or intermediates. Students interested in organic chemistry, biochemical synthesis and metabolism, or the development of new deuterated molecules are encouraged to contact ndf-enquiries@ansto.gov.au.

CONTACT:

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Prof. Rachel Codd

The University of Sydney

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RESEARCH AREAS:

Organic synthesis, isotope labelling, deuteration, drug discovery

*Molecular Deuteration for Clinical Agent Analogues

Project Details

The exchange of hydrogen-for-deuterium atoms in clinical agents is at the forefront of medicinal chemistry,since deuterated drugs can have favourable pharmacokinetic properties compared to the hydrogen parent [1].

The deuterated clinical agent – deutetrabenazine (AUSTEDOÒ) – was approved by the FDA to treat chorea (an involuntary movement disorder) associated with Huntington's disease in 2017. Compared to the hydrogen parent, deutetrabenazine has a longer half-life, which means patients need less frequent dosing. A reduced dose has significant benefit in terms of reduced toxicity and improved patient compliance. This landmark agent has spurred renewed interest in the production of deuterated clinical agents [1].

Synthetic chemistry can be used to access deuterated small molecule drugs, but other methods are required to access deuterated analogues of structurally complex natural products, which represent a major component of our medicines, as sourced from bacteria, plants and sponges.

One method that can be used to access deuterated forms of complex biomolecules is to culture a producing bacterium in medium supplemented with deuterated building blocks. This concept – known as 'precursor-directed biosynthesis' – aims to test the competence of the native biosynthetic machinery in accepting modified substrates, which may ultimately be incorporated into a novel drug scaffold. The method is attractive, since the bacterium itself is undertaking the synthetic chemistry that would ordinarily be very difficult to achieve in the laboratory.

In this project, you will be involved with the production of new deuterated building blocks and to use these as substrates in a precursor-directed biosynthesis approach with the ultimate aim to generate new deuterated analogues of clinical agents. This cross-disciplinary project will appeal to students who enjoy aspects of chemistry and chemical biology research.

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RESEARCH AREAS:

Organic synthesis, isotope labelling, deuteration, drug discovery

References

Mullard, A. (2016) Deuterated drugs draw heavier backing, Nat. Rev. Drug. Discov. 15, 219-221.

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Dr. W. Bret Church

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LinkedIn: link

RESEARCH AREAS:

Codon usage, Heterologous protein expression, Biological machinery for protein synthesis, pharmaceutical peptides, post translational modifications, Structure-based drug design.

*Enabling structure-based drug design for drug targets

Project Details

We have several important proteins which are drug targets, and are at various stages of the structure-based drug design process. Methods involve structural bioinformatics, modelling and experimental. In these projects the proteins are required in large quantities, due to the fact that high yield protein expression enables the projects which are often in a high throughput mode.

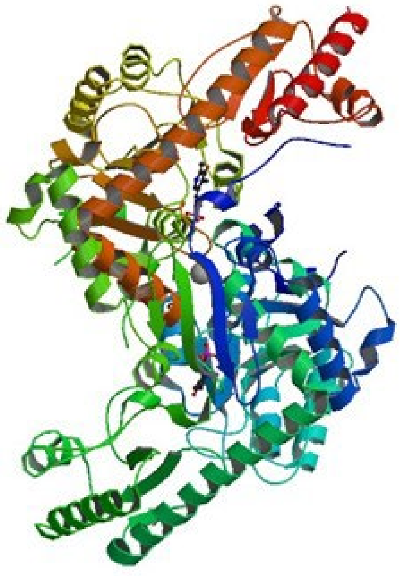
In collaboration with Dr Bret Church, University of Sydney, we are interested in kynurenine aminotransferase-2, due to its involvement in neurological disorders, and fragment-based drug design. Characterisation may involve SPR, NMR and crystallography.

A new student could begin with:

1. Protein expression, purification and crystallisation; or
2. Bioinformatics and drug design.

The student will become proficient in:

- Recombinant production of medically important proteins
- Molecular biology strategies
- Three-dimensional protein structures analysis
- Structure-based drug design



Human kynurenine aminotransferase-2

Enthusiasm for programming and scripting is desirable.

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Dr David Jacques

The University of NSW

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RESEARCH AREAS:

Codon usage, Heterologous protein expression, Biological machinery for protein synthesis, pharmaceutical peptides, post translational modifications, Structure-based drug design.

*Structural Virology of Human Pathogens

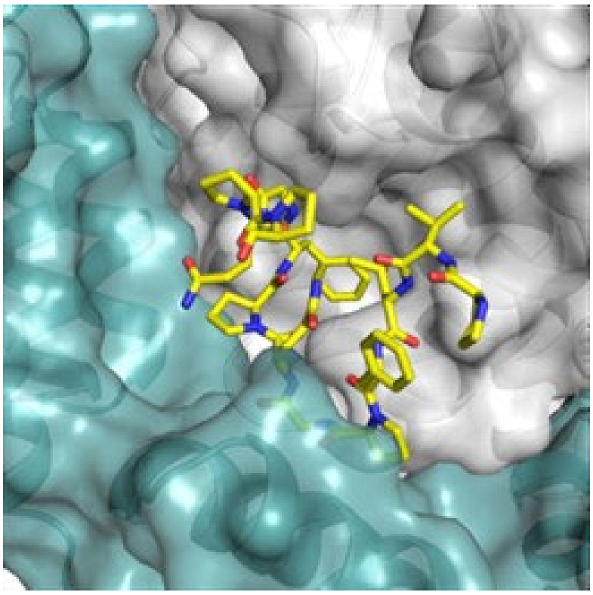
Project Details

We are interested in the structures of human viruses, their proteins, and the interactions they make with the host. Our lab has two major focuses:

(i) **HIV Capsid** – we are interested in the capsid of HIV as it represents the host-pathogen interface during the early stages of cell invasion. While it is of critical importance for the virus, much remains to be discovered about how it functions to engage with host motor proteins, protect the viral genome, facilitate reverse transcription, and penetrate the nu-clear envelope.

(ii) **Viruses of Bat Origin** – Many of the most lethal human viruses find their origin in bat species. These include SARS-CoV-2 (the virus responsible for the COVID19 pandemic), and the level 4 risk group pathogens Hendra, Nipah and Ebola viruses. It is thought that co-evolution with the bat species effectively 'primes' these viruses for lethality and pandemicity in humans. We are interested in understanding the molecular basis for the virus:host interactions (both human and bat) to understand how these viruses cause such lethal disease.

Both projects may inform the development of new approaches to antiviral treatment.



The HIV capsid engaging the essential host cofactor, CPSF6 (yellow sticks).

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Dr David Jacques

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RESEARCH AREAS:

Codon usage, Heterologous protein expression, Biological machinery for protein synthesis, pharmaceutical peptides, post translational modifications, Structure-based drug design.

A new student could begin with:

1. Protein expression, purification and crystal-lisation/cryoEM; or
2. Host-virus protein:protein interaction screening, and protein engineering; or
3. Virus characterisation by single molecule imaging methodologies.

The student will become proficient in:

- Recombinant protein production
- Molecular biology strategies
- Three-dimensional protein structures analysis
- Virology
- Imaging

Environment

ANSTO conducts and enables inter-disciplinary research using nuclear and isotopic techniques to address some of Australia's and the world's most challenging environmental problems, focusing on water resource sustainability, environmental change, and the impact of contaminants.

CONTACT:

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Environmental Research

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RESEARCH AREAS:

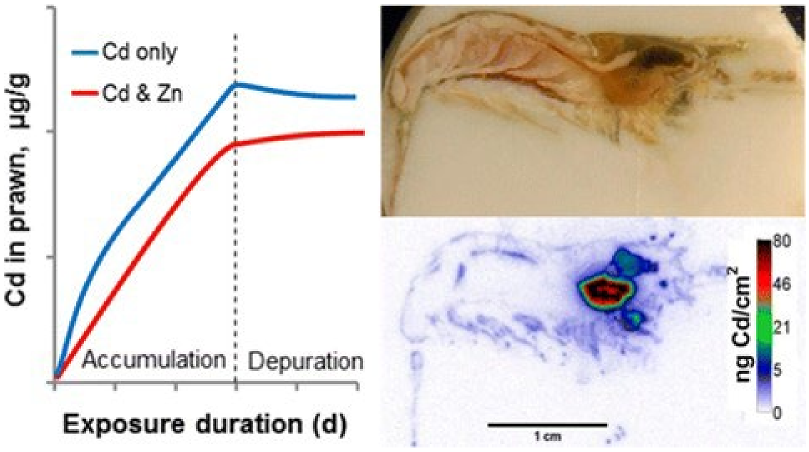
Environmental Science, Environmental Toxicology, Environmental Chemistry

Understanding contaminant bioaccumulation and effects in living aquatic organisms

Project Details

Aquatic ecotoxicology is primarily concerned with the bioaccumulation and effects of anthropogenic contaminants to a range of biota.

Traditional methods of assessing the bioaccumulation of contaminants by an organism have typically relied on destructive techniques, generally involving the dissection of internal organs, followed by acid digestion and analysis. To understand how organisms accumulate contaminants over time using these traditional methods, a large number of organisms was required to be sacrificed.



Bioaccumulation Kinetics and Organ Distribution of Cadmium and Zinc in the Freshwater Decapod Crustacean Macrobrachium australiense [1].

Trace amounts of gamma-emitting radioisotopes are valuable tools for studying contaminant bioaccumulation in living aquatic invertebrates. They reveal how nutrients or contaminants can be taken up through diet or respiration pathways and allow the influx and efflux of multiple contaminants to be analysed rapidly. Furthermore, autoradiography and XFM of cryosectioned organisms enables the organ distribution of accumulated metals to be visualised and quantified.

Using this method, organisms are snap-frozen and fixed to limit the mobilisation of chemical species, preserve the integrity of the organs and allow much higher resolution of organ-specific metal analysis compared to tradition dissection-digestion techniques.

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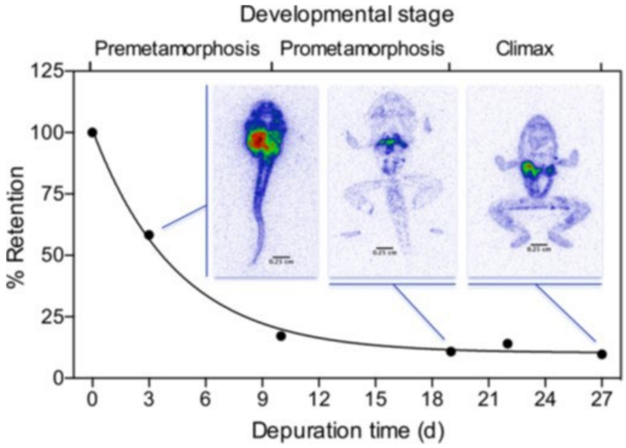
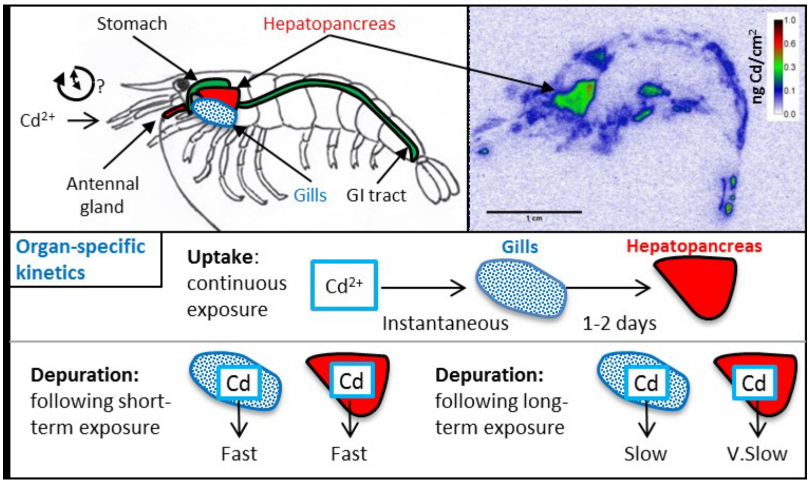
RESEARCH AREAS:

Environmental Science, Environmental Toxicology, Environmental Chemistry

Current research by our team includes understanding the impacts of stormwater pulses of metals on contaminant bioaccumulation, the effects of metamorphosis on metal bioaccumulation in aquatic insects and amphibians, and understanding the impacts of offshore petroleum infrastructure decommissioning on marine ecosystems.



Bioaccumulation and biodistribution of Selenium in metamorphosing tadpoles [2].



Metal Transfer among Organs Following Short- and Long-Term Exposures Using Autoradiography: Cadmium Bioaccumulation by the Freshwater Prawn Macrbrachium australiense *[3].*

References

[1] Cresswell, T., Simpson, S. L., Mazumder, D., Callaghan, P. D. and Nguyen, A. P. (2015). Bioaccumulation ki-netics and organ distribution of cadmium and zinc in the freshwater decapod crustacean *Macrobrachium australiense*. Environmental Science & Technology; **49**: 1182-1189 DOI: http://dx.doi.org/10.1021/es505254w.

[2] Lanctôt, C. M., Cresswell, T., Callaghan, P. D. and Melvin, S. D. (2017). Bioaccumulation and biodistribution of selenium in metamorphosing tadpoles. Environmental Science & Technology; **51**(10): 5764-5773 DOI: http://dx.doi.org/10.1021/acs.est.7b00300.

[3] Cresswell, T., Mazumder, D., Callaghan, P. D., Nguyen, A., Corry, M. and Simpson, S. L. (2017). Metal trans-fer among organs following short- and long-term exposures using autoradiography: cadmium bioaccumulation by the freshwater prawn *Macrobrachium australiense*. Environmental Science & Technology; **51**(7): 4054-4060 DOI: http://dx.doi.org/10.1021/acs.est.6b06471.

CONTACT:

Dr Cath Hughes

Isotope Tracing in Natural Systems (ITNS)

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RESEARCH AREAS:

Environmental isotope tracing

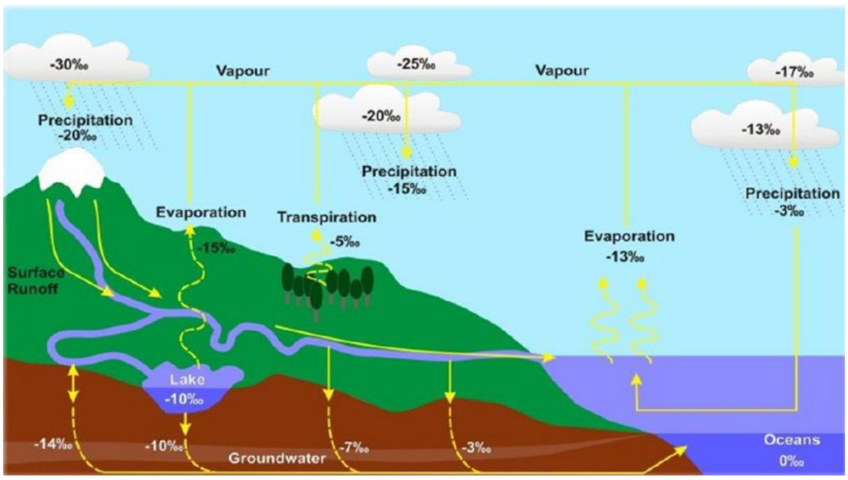
Applying stable isotope time series in rainfall, drinking water and vapour to water resources, climate, provenance and forensics

Project Details

Stable isotopes $\delta^{18}O$ and $\delta^{2}H$ in the water cycle can be used as tracers in water resource sustainability, climate research, food provenance and authenticity, and human and ecological forensics. Fractionation during phase changes and mixing through the hydrological cycle make $\delta^{18}O$ and $\delta^{2}H$ useful as hydrological tracers.

In Australia we are highly dependent on underground water for drinking and irrigation, particularly in rural and regional areas. Comparing $\delta^{18}O$ and $\delta^{2}H$ in rainfall, river water and groundwater can tell us how the groundwater got there – in many parts of Australia groundwater only recharges during large floods! Many cities and towns in Australia get their drinking water from big dams – the difference between rainfall and tap water isotopes can tell us how much of our water is being lost from evaporation.

Food and agricultural products also contain $\delta^{18}O$ and $\delta^{2}H$, and we can potentially use these isotopes to prove where they were grown or to detect adulteration – such as adding tap water to a product. Stable isotopes $\delta^{18}O$, $\delta^{2}H$ in hair keratin and fingernails reflect what you eat and drink – and that can give us clues to where you have been living. This also applies to wildlife forensics.



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Isotope Tracing in Natural Systems (ITNS)

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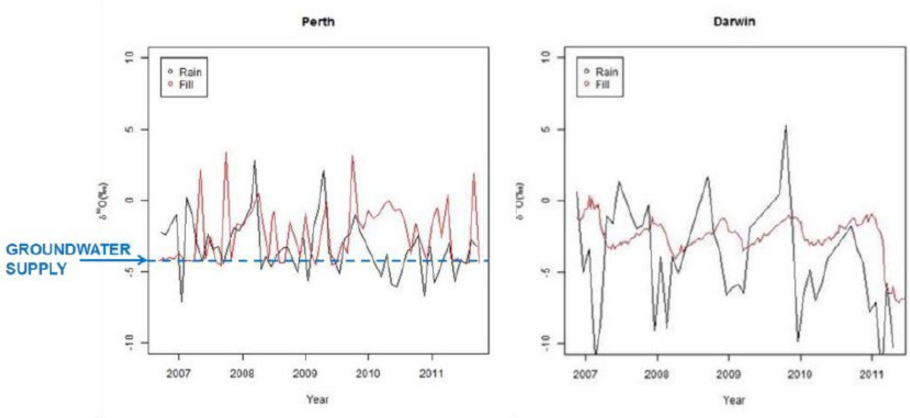
RESEARCH AREAS:

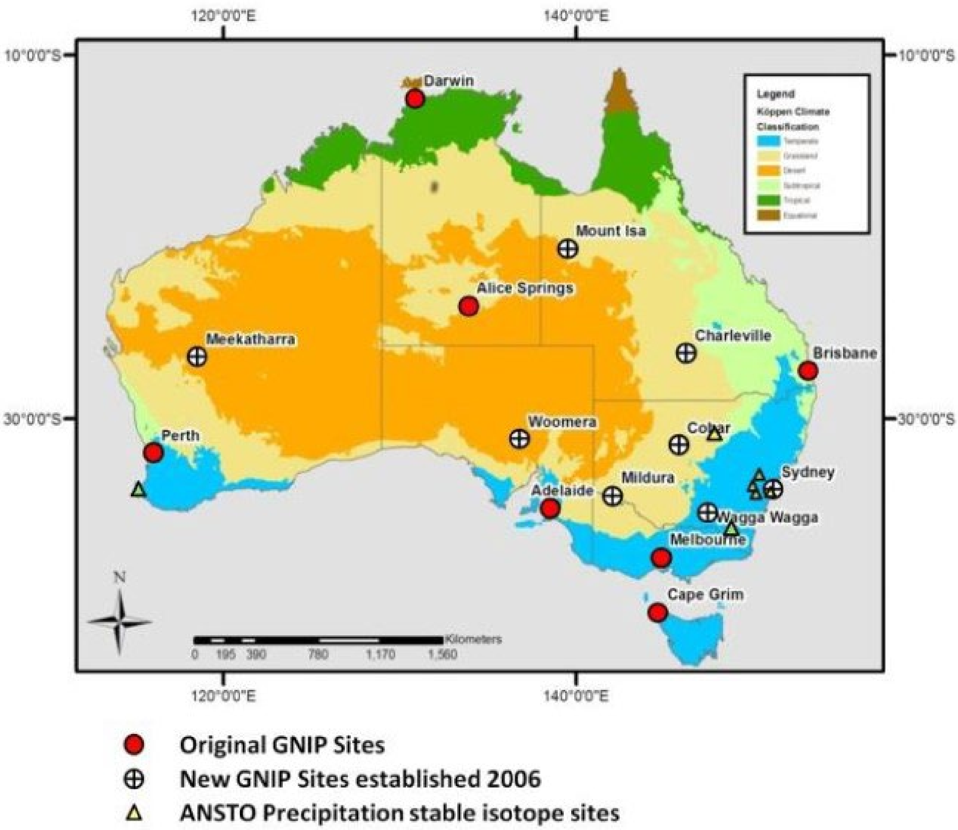
Environmental isotope tracing

All these applications need us to understand what determines the isotopes in rainfall and how that changes on the way to the tap or wetland or crop or product.



We have a unique decade long data set of monthly rainfall and tap data from 14 towns and cities around Australia. To interpret this for use in water resources, provenance, or forensics we need to analyse what is happening with water supply and climate at each of those locations, and to manage the data and results in a useable way.

Your project will enable us to use this data for a wide variety of applications and can be aligned to your area of interest and skills: environmental science, civil or environmental engineering, agriculture, physics, ecology, modelling or data management would be helpful backgrounds for this project.



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Dr Alan Griffiths

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Isotopes in Climate Change and Atmospheric Research

RESEARCH AREAS:

Radon-222 as a natural tracer in atmospheric studies

Characterising urban air pollution and atmospheric mixing using radon-222

Project Details

Once pollutants have been emitted from the surface, one of the two main factors controlling changes in the concentrations to which people are exposed is the atmospheric volume into which they are mixed (the other being removal by chemical conversions and surface deposition).

Radon is a reliable indicator of the vertical dilution of surface-released pollutants in the vicinity, and our research has shown that it can be used to form atmospheric stability scales that perform better than standard meteorologically-based scales in categorising urban and industrial pollution levels at night (Chambers et al. 2015a,b). By itself, or together with local or regional modelling techniques, radon can be used to help constrain urban emission estimates for a range of hazardous pollutants (Williams et al. 2016).

Radon-222 is a radioactive noble gas released naturally from terrestrial surfaces (rocks and soils). At ANSTO, radon is used as a tracer of atmospheric motions on different scales. ANSTO enjoys a unique position globally in this field of research, and our experimental methods are recognised as a world standard for high-sensitivity measurements of radon in the atmosphere. The breadth of scope of projects within the radon group al-low for student involvement in a number of areas depending on the individual’s skills and interests, including radon concentration and emanation measurements, analysis of radon, pollution and meteorological data sets, and modelling applications.

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Isotopes in Climate Change and Atmospheric Research

RESEARCH AREAS:

Radon-222 as a natural tracer in atmospheric studies

References

Chambers, SD, Wang, F, Williams, AG, Deng, X, Hua, Z, Lonati, G, Crawford, J, Griffiths, A, and Allegrini, I, 2015a: 'Quantifying the influences of atmospheric stability on air pollution in Lanzhou, China, using a radon-based stability monitor', *Atmos. Environ.* **107**, 233-243. doi:10.1016/j.atmosenv.2015.02.016.

Chambers SD, Williams AG, Crawford J and Griffiths AD, 2015b: 'On the use of radon for quantifying the effects of atmospheric sta-bility on urban emissions', *Atmos. Chem. Phys.* **15**, 1175-1190. doi:10.5194/acp-15-1175-2015.

Williams AG, Chambers SD, Conen F, Reimann S, Hill M, Griffiths AD, and Crawford J, 2016: 'Radon as a tracer of atmospheric influ-ences on traffic-related air pollution in a small inland city', *Tellus B* **68**, 30967. http://dx.doi.org/10.3402/tellusb.v68.30967

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Isotopes in Climate Change and Atmospheric Research

RESEARCH AREAS:

Radon-222 as a natural tracer in atmospheric studies

Antarctic / Southern Ocean studies using radon

Project Details

Radon is used to characterise air masses that travel across the Southern Ocean towards Antarctica, and determine their origin, composition and transport history. This assists in the determination of the impacts of atmospheric pollution from distant continents on the Antarctic environment.

In recent years, ANSTO has expanded its research in data-sparse regions in the Southern Hemisphere, focusing particularly on the Southern Ocean and Antarctica. In addition to long-term radon measurements at the southern tips of the major land masses of Australia and Africa, we now have radon detectors at Macquarie Is-land, Baring Head in New Zealand, King George Island and Terra Nova Bay in Antarctica, and aboard the Australian Research Vessels Investigator and Aurora Australis.

These radon measurements are being used to disentangle the relative contributions of near-surface synoptic transport, tropospheric subsidence and Antarctic katabatic outflows to the delivery of terrestrially-influenced air to the Southern Ocean marine boundary layer and Antarctic coastal regions (Chambers et al. 2018).

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Isotopes in Climate Change and Atmospheric Research

RESEARCH AREAS:

Radon-222 as a natural tracer in atmospheric studies

Radon-222 is a radioactive noble gas released naturally from terrestrial surfaces (rocks and soils). At ANSTO, radon is used as a tracer of atmospheric motions on different scales. ANSTO enjoys a unique position globally in this field of research, and our experimental methods are recognised as a world standard for high-sensitivity measurements of radon in the atmosphere.

The breadth of scope of projects within the radon group allow for student involvement in a number of areas depending on the individual's skills and interests, including radon concentration and emanation measurements, analysis of radon, pollution and meteorological data sets, and modelling applications.

References

Chambers SD, Preunkert S, Weller R, Hong S-B, Humphries RS, Tositti L, Angot H, Legrand M, Williams AG, Griffiths AD, Crawford J, Simmons J, Choi TJ, Krummel PB, Molloy S, Loh Z, Galbally I, Wilson S, Magand O, Sprovieri F, Pirrone N and Dommergue A, 2018: 'Characterizing Atmospheric Transport Pathways to Antarctica and the Remote Southern Ocean Using Radon-222', *Front. Earth Sci.* **6**, 190. https://doi.org/10.3389/feart.2018.00190

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Isotopes in Climate Change and Atmospheric Research

RESEARCH AREAS:

Radon-222 as a natural tracer in atmospheric studies

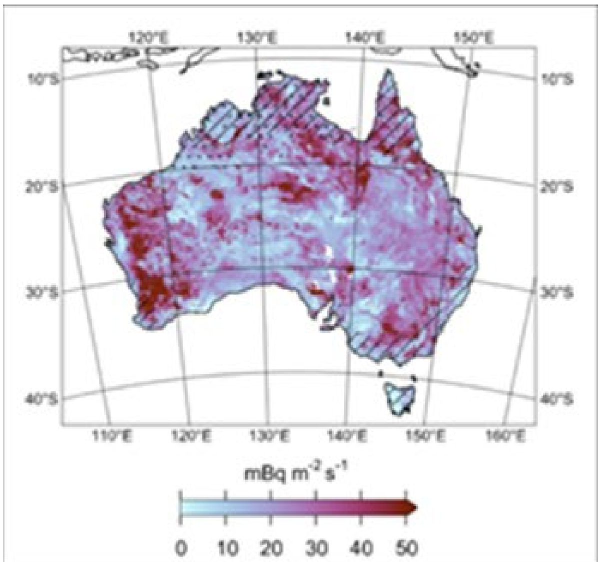
Regional soil sources and sinks of greenhouse gases and other important pollutants using radon

Project Details

Measurement precisions for a number of important soil-emitted trace gases like CH_4, N_2O and H_2 have improved dramatically in recent years, as has our ability to model atmospheric transport and our knowledge of radon emissions from soil (Griffiths et al. 2010).

New co-located data sets of concentration measurements of these trace gases together with radon are be-coming increasingly available from Australian baseline stations like Cape Grim and Gunn Point, the portable AIRBOX national air chemistry facility, and the Australian Marine National Facility RV Investigator. The prospect of using radon as a marker species for top-down estimates of regional emissions from the Australian land surface is therefore gaining credence as a complementary technique to Bayesian model inversions.

Radon-222 is a radioactive noble gas released naturally from terrestrial surfaces (rocks and soils). At ANSTO, radon is used as a tracer of atmospheric motions on different scales. ANSTO enjoys a unique position globally in this field of research, and our experi-mental methods are recognised as a world standard for high-sensitivity measurements of radon in the atmosphere.



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Isotopes in Climate Change and Atmospheric Research

RESEARCH AREAS:

Radon-222 as a natural tracer in atmospheric studies

The breadth of scope of projects within the radon group al-low for student involvement in a number of areas depending on the individual's skills and interests, including radon concentration and emanation measurements, analysis of radon, pollution and meteorological data sets, and modelling applications.

References

Griffiths AD, Zahorowski W, Element A and Werczynski S, 2010: 'A map of radon flux at the Australian land surface'. *Atmos. Chem. Phys.* **10**, 8969-8982.

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Isotopes in Climate Change and Atmospheric Research

RESEARCH AREAS:

Radon-222 as a natural tracer in atmospheric studies

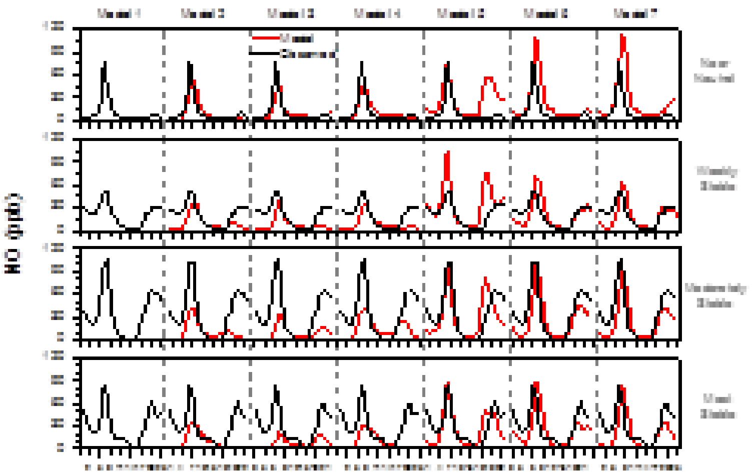
Evaluating regional chemical transport model performance using radon

Project Details

Concentrations of gaseous and particulate pollution within urban environments scale with population, and exposure to anthropogenic emissions is the cause of millions of premature deaths each year. Since it would be impractical and prohibitively expensive to establish dense pollution and meteorological monitoring networks within each city, Chemical Transport Models (CTMs) are becoming an important tool for urban planning purposes.

The ability of such models to represent actual pollutant concentrations within the urban 'zone of habitation' depends upon our understanding of physical mixing processes and secondary chemical reactions, as well as our ability to parameterise them. Evaluating the performance of CTMs, and making gradual improvements, relies on the ability to separate meteorological (mixing related) controls on pollutant concentrations from other influences.

One way to do this is through atmospheric "class typing" based on radon-derived atmospheric mixing states (e.g. Chambers et al. 2019).



Radon-222 is a radioactive noble gas released naturally from terrestrial surfaces (rocks and soils). At ANSTO, radon is used as a tracer of atmospheric motions on different scales. ANSTO enjoys a unique position globally in this field of research, and our experimental methods

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Isotopes in Climate Change and Atmospheric Research

RESEARCH AREAS:

Radon-222 as a natural tracer in atmospheric studies

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References

Chambers SD, Guérette E-A, Monk K, Griffiths AD, Zhang Y, Duc H, Cope M, Emmerson KM, Chang LT, Silver JD, Utembe S, Crawford J, Williams AG and Keywood M, 2019: 'Skill-testing chemical transport models across contrasting atmospheric mixing states using Radon-222', *Atmosphere* **10 (1)**, 25. https://doi.org/10.3390/atmos10010025