Materials Engineering at ANSTO

- The AINSE Researchers' Guide identifies the research topics in Materials Engineering.
- Access to the Materials Engineering facilities is through collaborative research.
- Identify the research topic which might incorporate your project.
- Draft applications including scientific objectives, background, and proposed method and program must be provided to the ANSTO research task leader by 15 August.
- The research task leader will advise the facility details and any other additional information to include in your application.

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Nuclear Materials Science

Australian and International Context

Research conducted under the Nuclear Materials Science programme seeks to address the emerging needs of materials and processes linked to the advanced nuclear fuel cycle. In this context, our research theme is focused on activities which can deliver benefits towards future environmentally sustainable energy production and to apply our expertise in other areas to support Australia's environmental challenges. Our programme seeks to establish collaborative research though partnerships, both national and international, that will deliver and promote the benefits of nuclear science and technology.

Research Topics

Our research group consists of a multi-disciplinary team of chemists, materials scientists, and technical staff working together to develop advanced technologies for fabricating materials and processes which are vital to the next generation nuclear fuel cycle. Recent research projects include:

- Development of selective adsorbent materials;
- Development of nano-scale materials and their structure-function relationships in nuclear applications.

Our Capabilities

The research team is building an effective capability in separations science and nano-scale synthesis with particular emphasis on the development of novel separations materials and engineering materials properties based on metal oxides; specifically modifying chemical, thermal or mechanical properties of materials using nano-scale processes. We have expertise in the synthesis of oxide and non-oxide materials using solution chemistry, vapour phase deposition and electrochemical methods. Our thin-films labs have the tools to prepare and characterise the evolution of materials prepared at several length scales. In addition, there are many investigative tools to study the structure-function relationships of materials, they include; vibrational spectroscopy (FTIR, Raman), UV-Vis spectroscopy, surface analysis by gas adsorption methods, particle size measurement and a radio-analytical chemistry lab for probing the adsorption of radionuclides with alpha and gamma spectroscopy. Instrumented micro-mechanical testing facilities (tensile, bending and indentation) are also available.

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AINSE

Applications of Ionising Radiation

Australian and International Context

Our research portfolio is designed to address emerging needs for new knowledge and instrumentation concerning the measurement and detection of ionising radiation, as well as the characterisation and assessment of nuclear signatures related to nuclear fuel cycle activities. We seek to establish national and international partnerships to pursue collaborative research which delivers on identified stakeholder needs in areas of direct "nuclear" relevance where our impact is substantial and of recognised benefit.

Research Topics

The research group consists of physicists, chemists, materials scientists, and technical staff with diverse backgrounds, working together to form a multi-disciplinary research team. The team works across three laboratories areas consisting of Detector Lab, Activity Standards Lab and Nuclear Forensic Lab. Our major research effort is directed towards an improved understanding of how ionising radiation interacts with matter, techniques for detecting such interactions and application specific interpretation of such interactions. Specific research areas include:

- Development of spectroscopic X-ray imaging technologies for diagnostic imaging and security screening applications.
- Micro- and nano-dosimetry for applications in medical physics, radiation protection and radiobiological research.
- The effects of ionising radiation on critical trace evidence.
- X-ray test pieces and algorithms that improve border security screening performance in maritime, vehicular and aviation contexts.

Our Capabilities

We have expertise invested in our people and facilities. Particular capabilities delineated by laboratory are provided below.

(1) Detector Lab
- Radiation transport modelling of ionising radiation interactions using the Geant4 toolkit operated in a computing cluster environment. Specialisation at the sub micron scale of size.
- Semiconductor based material assessment including electrical characterisation, charge collection imaging, current pulse analyses and deep level transient spectroscopy.

(2) Activity Standards Lab
- High precision radioactivity measurements (national standard).
- Radioisotope assay of unknown radiological and nuclear materials.

(3) Nuclear Forensics Lab
- Nuclear signature characterisation.
- Traditional forensic techniques in a radiological context.

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AINSE

Nuclear Materials Modelling and Characterisation

Australian and International Context

Our strategic directions are based on the need for innovative materials for safe, environmentally friendly, reliable, and cost effective energy production to support the future well being of Australians and to promote domestic and international research partnerships in nuclear science and technology. The current research profile is based on applied and discovery research on the solid state physics and chemistry of advanced materials for use in extreme environments of radiation, temperature, and pressure. These studies include materials of interest in the high technology sector, e.g., oxide based compounds with useful electronic, ionic, or magnetic properties.

Research Topics

The research group consists of physicists, chemists, materials scientists, and technical staff with diverse backgrounds, working together to form a multi-disciplinary research team. The *modus operandi* of the group involves the application of both experimental and atomistic modelling techniques in an iterative loop: providing high quality experimental data supported by validated computational models. Currently, our major research effort is devoted to a fundamental understanding of the interaction of radiation with materials. This exciting research area has several applications ranging from fission and fusion energy materials to device physics to radiation detection and human health, among others. We also have extensive expertise in the mineralogy, geochemistry, and radiation effects of Th-U minerals and conduct laboratory based studies of actinide crystal chemistry and aqueous speciation. Thus, we encourage research collaboration in the following areas:

- Fundamentals of radiation damage in oxides (e.g., fluorite, pyrochlore, spinel, and garnet structure types) and intermetallic compounds. This work involves both *in situ* irradiation of TEM samples and ion irradiation of bulk materials.
- X-ray, neutron, and electron scattering studies of the structure, bonding, and order-disorder behaviour of materials relevant to fission, fusion, and other advanced energy systems.
- Synthesis and characterisation of materials containing actinides and other radionuclides for studies of the crystal chemistry, physical properties, phase transitions, and aqueous dissolution behaviour.

Our Capabilities

We have expertise in the synthesis of materials, electron microscopy and microanalysis, X-ray and neutron diffraction, and a range of spectroscopic methods including vibrational spectroscopy (FTIR, Raman), electron energy loss spectroscopy, X-ray absorption spectroscopy, UV-Vis and Diffuse Reflectance, and X-ray photoelectron spectroscopy. For atomistic modelling approaches, we are supported by ANSTO's advanced computing facilities and currently use molecular dynamics (MD) simulations to study the energetics and migration behaviour of defects, thermal spikes, and large collision cascades in materials. We also use density functional theory (DFT) applied to structure, bonding, phase stability, mechanical properties, and the energetics of defects in materials. We manage the following ANSTO facilities:

- X-ray diffraction laboratory, with a range of detectors, sample heating and cooling.
- SEM laboratory with capabilities in high-resolution imaging, chemical microanalysis and mapping, and electron backscatter diffraction and mapping.

- TEM laboratory with STEM imaging, high-resolution imaging, chemical microanalysis, and electron energy loss spectroscopy and mapping capabilities.
- Access to DL_POLY3 for detailed MD simulations of the dynamic behaviour of materials.
- Access to DFT codes including SIESTA, Dmol3, and VASP for *ab initio* studies of energetics and electronic properties of materials.

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Structural Integrity Program

Australian and International Context

The Structural Integrity Programme undertakes research in the area of the behaviour of material in extreme environments; principally neutron irradiation, high temperature and high pressure. A major focus is to develop an understanding and be able to predict the behaviour of materials under future Generation IV (GenIV) and fusion power reactor operating conditions and to determine the effect that property changes have on the integrity of the structures that make up the reactor systems. This includes an understanding of the effect of neutron irradiation on structural materials and how these changes affect the integrity of welds. The outcomes of the programme include fundamental knowledge on the effects of radiation on materials, and of the development of residual stresses in welds due to materials properties and weld procedures.

Research Topics

Our research team consists of a multi-disciplinary group of physicists, materials scientists, materials engineers and metallurgists with a wide range of research and industrial experiences. We have some of the most comprehensive mechanical testing capabilities in the region and specialise in the generation of high quality results from such tests. The overall objective is to understand the behaviour of materials under extreme environments, with a major focus being the future application in nuclear power generation in fission and fusion reactors. The activities are undertaken in several areas detailed below.

- Understanding the effects of neutron irradiation on the properties of materials for use in nuclear applications, particularly in GenIV fission and future fusion reactors. The materials include steels (ferritic, martensitic, austenitic etc), zirconium alloys (including Zircaloy-4, Zr-2.5Nb and Zr-3Sn), a variety of dispersion strengthened materials (such as oxide dispersion through nano-sized particles of yttrium oxide), various aluminium alloys (widely used in research reactors) and various other metallic and non-metallic materials.
- Modelling of welds in structural materials – this is required to enable the performance of structures to be understood – particularly multi-pass welds that have the potential to develop significant residual stresses. The weld modelling is supported by modelling of the development of microstructure
- Development of knowledge of materials properties at high temperature and extend current defect and structural assessment codes applicable to next generation power plants. Particular emphasis is placed on creep and creep/fatigue interactions that result from cycling of high temperature engineering plant. Contributions are being made in the development of international assessment protocols such as the R5 and ASME-EPRI codes.

Our Capabilities

Our research programmes are supported by a range of experimental facilities. Significant investment has recently been made in the development of facilities for the preparation, handling and testing of radioactive materials. An active metallography facility (for low level radioactive materials) is under construction and a suite of hot cells (for high activity materials) are currently in the design stage. Other major facilities include:

- Mechanical testing – tension, compression, fracture toughness, fatigue and creep etc. at temperatures from -196˚C to in excess of 1,500˚C, in various environments including air, argon and vacuum.

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- Finite element modelling capability centred around the ABAQUS package with elastic/plastic capability.
- Capabilities for measuring residual stresses including: neutrons (KOWARI instrument on OPAL), X-ray, contour method, slitting technique and others
- SEM, TEM and FEGSEM facilities including EBSD
- Materials fabrication capability including mechanical alloying, hot isostatic pressing (HIP), cold isostatic pressing (CIP)

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