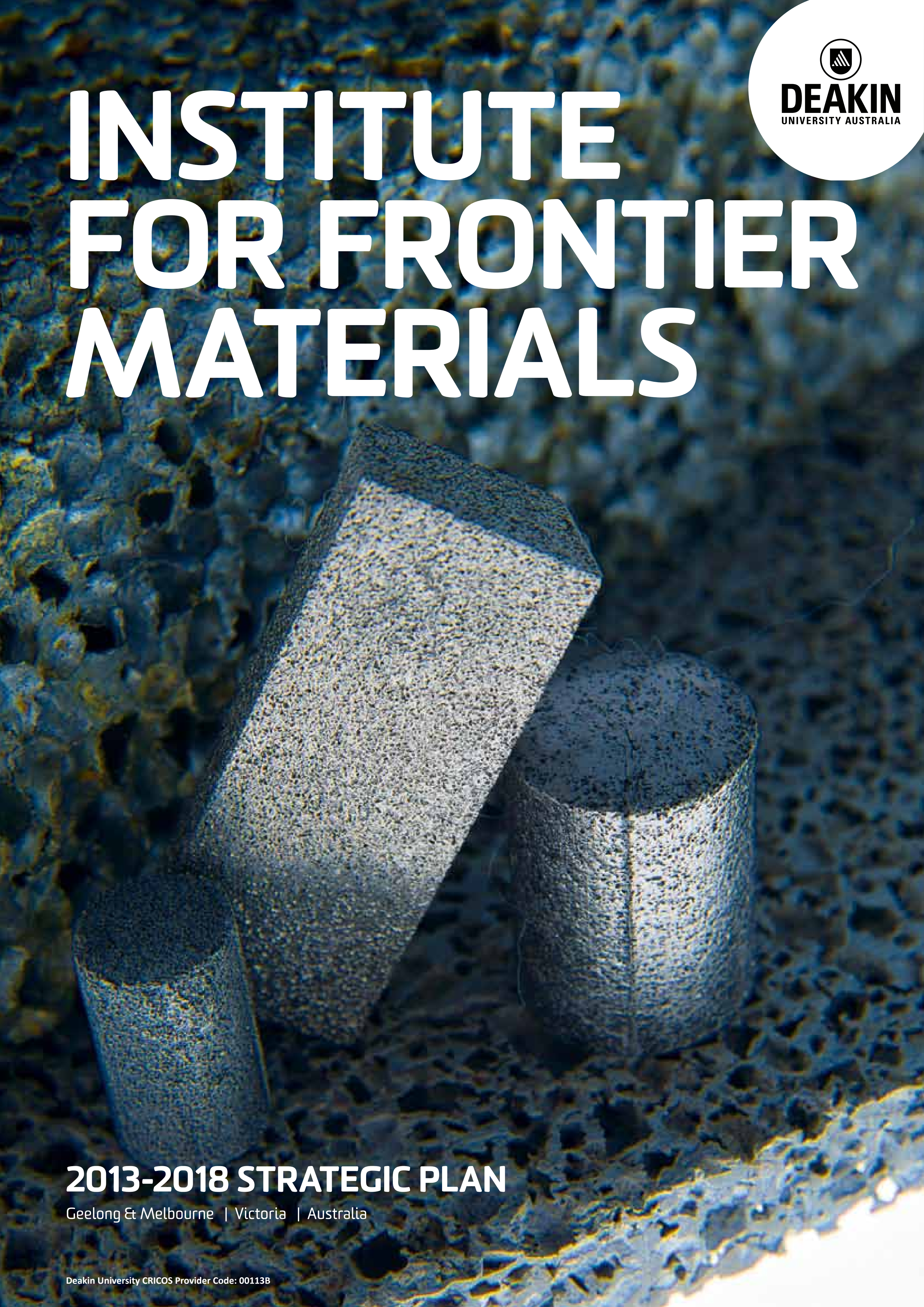

INSTITUTE FOR FRONTIER MATERIALS

DEAKIN
UNIVERSITY AUSTRALIA

2013-2018 STRATEGIC PLAN

Geelong & Melbourne | Victoria | Australia

Deakin University CRICOS Provider Code: 00113B

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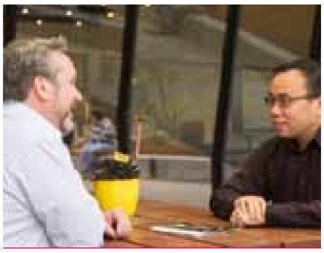
INTRODUCTION AND CONTEXT

Welcome to the first Strategic Plan of the Institute for Frontier Materials (IFM).

The Institute for Frontier Materials is focused on developing new materials to address key challenges in society with high-quality postgraduate and postdoctoral training at the forefront of our aspirations.



Above: IFM Director Professor Peter Hodgson and Deputy Director, Professor Xungai Wang outside the newly refurbished building at Geelong.

The formation of IFM underpins Deakin University's commitment to materials and manufacturing related research that will make a difference to the communities that we serve. Our Strategic Plan builds upon the Deakin University Strategic Plan *LIVE* the Future.

IFM headquarters is located within the Geelong Technology Precinct (GTP) on the Waurn Ponds campus. This precinct is also the home to start-up companies such as Carbon Revolution and our major initiative related to carbon fibre research, Carbon Nexus.

It is expected that over the timeframe of this strategic plan a number of start-up companies and spin-offs from our own research will play a major role in establishing the GTP as a model for university – industry engagement and the development of future industries for the Geelong region.

IFM has developed from a very small centre within the School of Engineering more than a decade ago to today, including more than 270 researchers and postgraduate students from 40 countries. A major focus over this time has been to cover the full spectrum of research from fundamental discovery research through market driven applications. Through this IFM has maintained a steady portfolio of industry partners while also achieving exceptional ratings in our research areas in the past two ERA assessments.

Our future challenge is to continue to grow while maintaining our commitment to excellence and relevance in the face of major changes to manufacturing related research in Australia.

Another aspect of IFM has been its strong focus on internationalization, with major initiatives in both India and China. These countries have been a source of both high-quality research students and of opportunities for applying our research in these rapidly expanding economies.

In the coming five years, through the platform of this Strategic Plan, IFM will approach exciting new frontiers in the development of materials to meet key societal challenges.

As a response to this, IFM has embraced a new structure to allow us to tackle more complex problems of national and international importance in the areas of energy, health, environment, as well as manufacturing. The Institute for Frontier Materials aims to develop new materials and structures that are not only affordable, but also have a low societal cost of manufacture, usage and recycling.

OUR VISION

To lead and inspire innovations in Materials Science and Engineering that have a transformational benefit to society.

VALUES

Our values are consistent with those of Deakin University, articulated in *LIVE* the Future.

Nonetheless, it is important to address Values here in a specifically IFM context, as these Values define and underpin the way we work, behave and make decisions.

INSPIRATIONAL

- We will inspire innovation and foster creativity in our staff and students in the field of materials research such that the IFM experience is recognised world-wide as the gold standard.

EXCELLENCE

- Through the quality/excellence of our research we will achieve both national and international recognition and harness the benefits that accompany this recognition.

GROWTH OF KNOWLEDGE

- Through education, training and research, we will share the knowledge that we have generated through engagement across academia, industry and the community generally. We will use our knowledge and expertise to develop real world applications and have a positive impact for our communities.

FAIRNESS AND EQUALITY

- Through all of our activities, IFM will endeavour to:
  - Promote academic freedom
  - Reward and recognise the individual
  - Provide professional development at all levels
  - Foster a culture of inclusion and open-mindedness in both our internal and external activities.

INTEGRITY

- We will treat our staff, students and external personnel in an honest, transparent and ethical manner and our expectation is that this behaviour will be reciprocated in all of our dealings.

COLLEGIALITY

- We will encourage collegiality across the institute through open communication and by promoting formal and informal collaboration and networking.

Top: Deakin's LIVE the future strategy

Right: Dr Ben Allardyce and Dr Rangam Rajkhowa examine a solution of processed silk fibres.

MISSION

Our mission is to foster innovation and excellence in materials science and engineering research with the aim of addressing the critical societal objectives:

- Innovative manufacturing technologies
- Energy efficiency, resource and infrastructure sustainability.

We aspire to provide the highest quality research training and education to sustain the advancement of society.

DELIVERING THE IFM MISSION AND VISION

The future development of IFM and its ability to deliver against the Vision and Mission depends upon success in a number of key areas. We have identified eight broad areas under which there are 14 goals and associated strategies.

These areas focus on improved excellence in research and industry engagement, and also on developing our people and the culture of IFM as well as the infrastructure required to undertake leading edge research.

A key element is to support our mission of providing the highest quality research training for students, research fellows and staff.

STRATEGIC GOALS

RESEARCH

STRATEGIC GOAL 1

Develop strategic research areas that are aligned with IFM's mission

STRATEGIC PRIORITIES

- Appoint theme leaders to co-ordinate and drive the research activities within the Innovative Manufacturing & Energy Efficiency, Resource and Infrastructure Sustainability Themes

FUNDING/RESOURCES

STRATEGIC GOAL 2

Diversify funding sources to create funding stability over the longer term

STRATEGIC PRIORITIES

- Increase our industry, business and government research income by identifying potential partners that will lead to long-term effective partnerships
- Create internal "flagships/centres" that utilise existing and emerging research strengths: energy/manufacturing/corrosion/composites
- Identify targets for IFM to lead in large collaborative research programs (e.g. CRC, CoE, Transformation hubs) and commit core teams to develop and drive these bids
- Develop at least one MARQUE partnership by 2016
- Explore alternative fund sources (e.g. philanthropic, foundations, alumni etc.).

INDUSTRY ENGAGEMENT AND COMMERCIALISATION

STRATEGIC GOAL 3

Continue to deliver innovative solutions to the marketplace

STRATEGIC GOAL 4

Develop a major technology by 2018

STRATEGIC PRIORITIES

- Create an industry engagement strategy in collaboration with Deakin Research Commercial
- Investigate, develop and communicate translation pathways
- Develop a reward and recognition system for translation of ideas
- Develop at least one technology demonstrator.

INTERNATIONALISATION

STRATEGIC GOAL 5

Develop key long-term, high-impact collaborations with strategically aligned quality organisations and partners

STRATEGIC PRIORITIES

- Strengthen existing collaborations in India
- Strengthen existing collaborations in China
- Identify and develop strong links in Europe.

PEOPLE

STRATEGIC GOAL 6

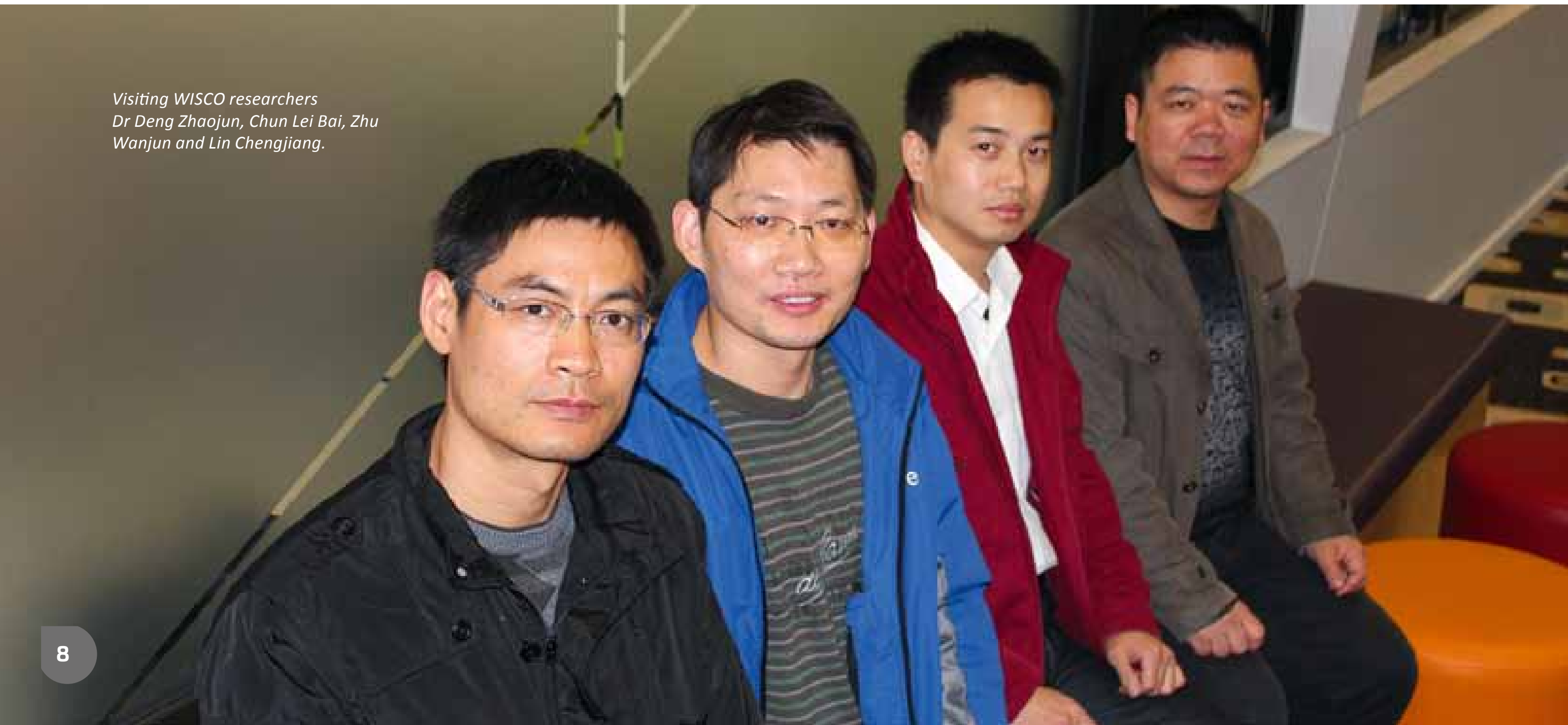
Sustain an environment that attracts and retains high-quality staff and students

STRATEGIC GOAL 7

Build the capability of staff to support and deliver world class research and innovation

STRATEGIC PRIORITIES

- Develop clearer career pathways for staff
- Develop a succession plan within research groups
- Maintain a watching brief for high-quality staff who add
  to IFM capacity and capability
- Develop a professional development strategy for staff.



Visiting WISCO researchers Dr Deng Zhaojun, Chun Lei Bai, Zhu Wanjun and Lin Chengjiang.

CULTURE

STRATEGIC GOAL 8

Foster a culture of innovation, collaboration and excellence by ensuring staff are aligned to the goals of IFM and Deakin

STRATEGIC GOAL 9

Continue to improve and promote a safe working environment within IFM

STRATEGIC PRIORITIES

- Involve staff in the implementation of the guiding principles and goals
- Enhance collaborative and co-operative relationships across all research groups
- Provide education and training for professional staff to remain current with applicable new laws and technologies
- Build a sustainable safety culture through the delivery of safety education to all staff and students.
- Promote a culture of inclusion and open-mindedness by providing quality social interactions/events.

EDUCATION

STRATEGIC GOAL 10

Deliver a unique training experience which produces world-class researchers

STRATEGIC GOAL 11

Provide distinctive education and training for undergraduate students in the area of materials science and engineering

STRATEGIC PRIORITIES

- Enhance the postdoc/HDR experience to develop future leaders
- Harmonise standards for supervision training
(best practice)
- Promote opportunities for early career researchers to contribute to Deakin's teaching activities
- Continue to participate in Curriculum discussions with Deakin Executive in planning for IFM involvement in potential new units, courses.

MARKETING, COMMUNICATION & OUTREACH

STRATEGIC GOAL 12

To be globally recognised as a leader in materials research and innovation

STRATEGIC GOAL 13

To be recognised within Deakin and the communities that we serve

STRATEGIC PRIORITIES

- Develop communication and marketing plans
- Develop an ALUMNI program

INFRASTRUCTURE – BUILDING/EQUIPMENT

STRATEGIC GOAL 14

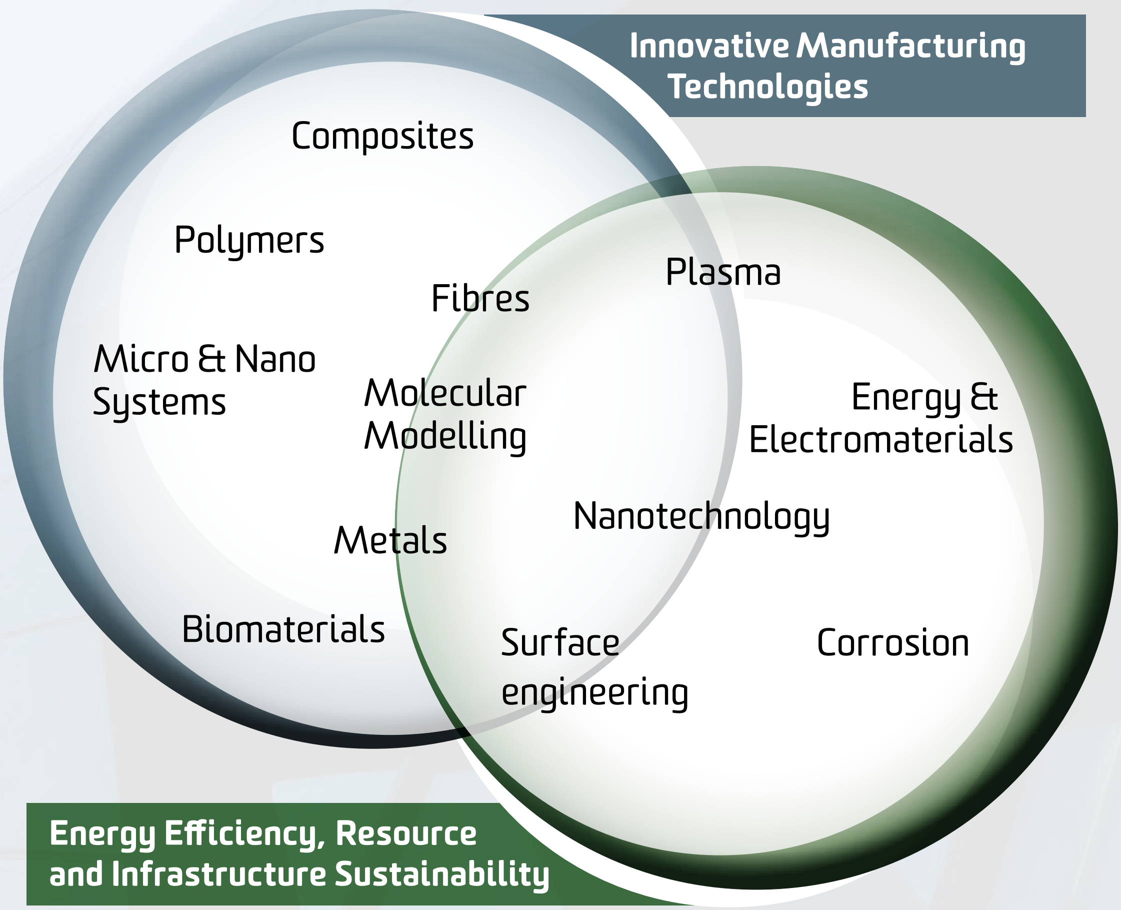
Develop an infrastructure plan for the next five years

RESEARCH

THEMES

Our key research areas fall under two main themes:

- Innovative manufacturing technologies
- Energy efficiency, resource and infrastructure sustainability



KEY RESEARCH AREAS

IFM researchers bring together engineering, chemistry, materials science, physics, biology, mathematics and other disciplines to develop new materials and engineering solutions.

Above: Biomaterials

Below right: Researchers in ACES electrochemical laboratory examining ionic liquids.

The scope of work in each of our key research areas is described below.

BIOMATERIALS

In the area of polymeric (soft) biomaterials, our research activities focus on two key areas: haematopoietic stem cells (HSC) and short nanofibres.

HSC are the key to clinical treatments such as stem cell transplants to treat leukaemia. IFM researchers are addressing the major challenge in the field of HSC biology: developing systems that support HSC self-renewal and controlled differentiation in vitro. Achieving HSC expansion in vitro, while retaining the cells' multipotency, is the key to attaining higher stem cell transplant clinical success.

IFM is at the forefront of the development of a new class of nanomaterials, known as short nanofibres. Nanofibre technologies world-wide need to increase production as available production methods cannot keep pace with increasing demand. IFM is tackling this challenge by developing a new method for large-scale, low-cost production of short nanofibres. Novel applications for short nanofibres include high-level filtration of small particulates, tissue engineering and enzymes.

In the field of metallic biomaterials our research focuses on the development of novel materials and biocompatible modified surface technology to solve some of the challenges facing biomaterials and address health and medical issues.

Metallic biomaterials are commonly used to make medical implants such as artificial hip joints, bone plates and heart pacemakers, due to their reliable mechanical and biological performance. The challenge is to reduce costs and improve longevity by developing functional implants with excellent biocompatibility and bioactivity.

Current research includes projects on titanium and its alloy scaffolds; biodegradable magnesium alloys; and biocompatible and bioactive surfaces.

COMPOSITES

Carbon fibre composites are being increasingly used across a wide range of industries, such as aerospace, automotive, oil and gas, clean energy and sporting goods, where they are replacing traditional materials such as steel and aluminium. Global carbon fibre demand is forecast to increase at an annual rate of 13-17% and will exceed 200,000 metric tonnes by 2020. Australia's composites industry is currently in a significant growth phase, with a number of established aerospace companies ramping up production of carbon fibre composites, and the growth of new companies producing innovative materials for automotive and industrial applications.

The main challenges for industry in the area of carbon fibre are to develop new low-cost automotive grades of carbon fibre, new high performance carbon fibre for aerospace applications and new carbon fibre coatings to improve handling and fibre matrix adhesion. These new fibres and treatments must be designed with a focus on the evaluation of the final composite component. While advances in automated fibre placement have resulted in faster composite lay-up, the remaining challenge for carbon fibre composites is to reduce the cure cycle time to under 10 minutes in order to keep up with automotive production rates.

The Composites group aims to create new grades of low-cost carbon fibre, new high performance fibres, new surface treatments and sizing for fibres and better understanding of structure property relationships in carbon fibre.

Top: Researchers using the Scanning Electrochemical Microscope to probe the electrochemical response of new corrosion inhibitors for magnesium alloys.

Above: Electromaterials & energy research is to develop new materials and understanding to support the development and integration of new energy technologies with improved safety, efficiency and durability

CORROSION

Corrosion, particularly localised corrosion, is a critical issue which affects the reliability, durability and sustainability of major civil industrial infrastructure. Such infrastructure is vital for the provision of the nation's essential services and the maintenance of its economic activities, such as oil and gas pipelines, mining and offshore infrastructures, water and desalination facilities, chemical and petrochemical plants. The CSIRO estimates that corrosion costs Australia $13 billion per year. The group's research aims are to develop safer energy pipelines with longer service life and thus result in reduced maintenance costs for the oil and gas and desalination industries. Current and future research work will include:

- Leading Energy Pipeline CRC on energy pipeline corrosion, coating, cathodic protection and life prediction research (current focus is on external oil and gas steel pipeline).
- Substantial research on the performance and behaviour of stainless steels in seawater conditions (as a part of a National Centre of Excellence in Desalination research).
- Both fundamental and industry research projects on corrosion inhibition, such as research on CO2 corrosion in oil and gas environments, on pitting corrosion in oil pipelines, and on welding zone corrosion of stainless steels.
- Expand corrosion research to include offshore oil and gas structures, mining infrastructures, and defence equipment.

ENERGY AND ELECTROMATERIALS

The group's research aims are to develop new energy technologies through the creation of new electroactive materials (electromaterials). Energy generation and energy storage are key issues facing society due to the need to replace finite and polluting fossil fuels as an energy source. The problems to be overcome mainly relate to safety (high energy batteries can lead to fires or explosions, e.g. Boeing Dreamliners), energy density (i.e. allowing electric vehicles to travel over greater distances on a single charge) and cost (i.e. current technologies are prohibitively expensive for large-scale application in electric vehicles, or for industrial or domestic applications).

Current research into new materials seeks to enable new device chemistries – e.g. metal-air or sodium based batteries – or to improve the performance, safety and durability of existing technologies such as lithium-ion batteries.

The following are essential in order to progress the group's research:

- Development of characterisation techniques to probe the fundamental chemical and electrochemical mechanisms in a variety of novel battery technologies.
- Understand and control reactive metal surface/electrolyte interactions of relevance to electrochemical devices and corrosion processes.
- Fundamental understanding of ionic structure and transport mechanisms in ion transport materials using advanced modelling and characterisation techniques.
- Development of redox active electrolytes and electrocatalytic electrodes for thermal energy harvesting.

LIGHT METALS

Light metals are essential for efficient transport. They provide structural strength at low weight, thereby lowering energy consumption. To obtain the emissions savings that are increasingly being required in this sector, magnesium and titanium are (and will continue to be) re-examined as desirable candidates for many components. Advances in these applications also promise to open up new manufacturing opportunities.

To increase the use of light metals in energy saving applications, the Light Metals group is developing ways to reduce material costs, creating new alloys with improved performance and deriving more accurate models of material behaviour. Current and future research activities include

- Light alloy cost reduction through improved formability
- New Mg and Ti based light alloys with improved performance – including functional capability, such as thermoelectric power generation from waste heat
- Developing new, more accurate models of material behaviour for use in 'virtual' engineering and alloy design.

Top: Molecular modelling

Above: Researchers at IFM are exploring novel, unique functions and applications of nanofibres and developing new nanofibre production and assembly technologies.

MICRO AND NANOSYSTEMS

The Micro and Nanosystems group research focuses on the development of novel, porous, environmentally friendly materials and also the development of molecular diagnostic technology for a healthier community.

One of the group's key strengths is the design, fabrication and characterisation of porous nanoparticles at room temperature. The porous nanoparticles (20 nm ~ 200nm in diameter) contain a network of interconnected pores (~2 nm in diameter). This makes the materials suitable for transporting chemicals into plant cells, animals and humans.

The group's knowledge and expertise has facilitated a major breakthrough in the fabrication and functionalisation of porous materials with pores at sub-nanometre level and unique surface properties for water treatment and desalination.

The properties displayed by these materials are being explored for the development of new micro and nano-devices which may be utilised in diagnostic technologies.

MOLECULAR MODELLING AND SIMULATION

The group's research involves the development and application of advanced computer modelling at the molecular level, based on fundamental principles of chemistry, physics and mathematics, to predict properties and behaviours of any substance composed of atoms and molecules.

The key concept is the ability to link structure at the molecular level with the macroscopic properties of the system – such as binding affinities and other thermodynamic quantities, transport properties, catalytic properties, etc. In partnership with experimental findings, predictions can help frame hypotheses to account for observed experimental behaviours and indicate clear pathways for testing these hypotheses.

As well as partnering with hypothesis-driven experimental research that has clear goals, predictions can also provide strong guidance for industrially-focused projects where questions of formulation and types/numbers of additives can be addressed quickly and economically.

Provided there is a way to describe the system/material at an atomistic or molecular level, there is no bar in principle to the type of material or system that can be modelled.

The group's modelling abilities form a platform capability that can, in principle, span IFM's entire range of activities and interests.

The group's current and future work includes:

- Structure-property relationships of interfaces between biological matter for applications in a wide range of areas from medical diagnostics, to meta-materials generation strategies; from medical implant technologies, through to fundamental research on biomineralization.
- Prediction of formulation–property and structure–property relationships associated with high-performance carbon-fibre composite materials.
- Development of strategies to predict structures, properties (e.g. mechanical or catalytic) and behaviours of challenging protein systems of high interest to both the personal care and pharmaceutical industries.
- Methodological development and force-field development in the field of molecular simulation in general.

NANOFIBRES/FUNCTIONAL FIBRES

Functional fibres and fabrics have special properties to make them, for example, resistant to heat, very strong, waterproof or resistant to abrasion. IFM researchers are exploring novel properties and applications of functionalised fibres and fabrics, such as a coating technology for producing durable functional fibres and fabrics. Applications of this work include functional fibres and fabrics for personal protection, energy harvesting, biomedical tissue scaffolding and desalination of water.

Nanofibre-related research at IFM aims to address key challenges which hinder the practical applications of nanofibres. This includes exploring novel, unique functions and applications of nanofibres, and developing new nanofibre production and assembly technologies. Although nanofibres are already being used commercially, their potential has not yet been fully explored. The group is developing advanced electrospinning technologies for large-scale nanofibre production.

Top: Nanotechnology focuses on two main areas: nanotechnology and energy storage.

Above: Carbon fibre line.

NANOTECHNOLOGY

The Nanotechnology Group focuses on two main areas: nanotechnology and energy storage. The group's aim is to develop novel nanomaterials and utilize nanotechnology to solve some of the current challenges in energy storage (battery and supercapacitors), environmental protection and health and medical issues.

The group's current and future research includes:

- Development of new nanomaterials with 2D and 3D structure, high porosity, and large surface area with superb properties and functionalities.
- Development of new large-scale production techniques for porous nanomaterials and their applications for oil spill cleaning and water/air purification as well as energy storage, e.g. new porous Boron nitride and Boron carbon nitride nanosheets with superior sorption and cycling stability performance for water cleaning and storing clean energy.
- Continue to improve battery/ supercapacitors with new electrode materials and new design. Production of batteries for electric vehicles and large-scale energy storage.
- Development of advanced manufacturing processes for advanced composite materials and products. Boron nitride nanotubes have been added to polymer and metal matrices to produce nanocomposites with increased strength and better thermal properties.
- Contributions to drug delivery and bio applications.

NATURAL FIBRES

Natural fibre research at IFM is closely aligned with the research priorities of Australia's $4 billion natural fibre industry. Australian wool and cotton export is ranked world number 1 and number 3, respectively. There is also growing use of some natural fibres (e.g. silk) for high-end applications, such as biomedicine. The key issues for natural fibres are value adding and long-term sustainability. The group is tackling these challenges by developing more environmentally friendly ways of processing natural fibres, using natural fibres for novel applications, and identifying, as well as bio-mimicking, the unique features of natural fibres and fibre structures. The group's current and future research includes:

- Water and energy saving technologies for processing natural fibres (e.g. wool, cotton, hemp)
- Biomedical applications of natural fibres (e.g. silk fibre, silk powder, and silk nanofibres)
- Bio-mimicking of natural fibre structures (e.g. wild silk cocoon) to develop functional materials and light-weight structures.

PLASMA

Plasma research at IFM aims to develop a fundamental understanding of a platform technology, in order to generate improved processes and materials (down to the nanoscale). Application of these technologies may be used to solve environmental, health and industrial problems.

Plasma may be described as a room temperature physical process for producing reactive species that allows surfaces/ interfaces to be altered, new structures to be grown, bacteria and cancer cells to be killed, and the chemistry of both liquids and solids to be altered. Thus, plasma can be used to make better performing materials and processes to address challenges in key research areas, such as energy capture or energy storage, biomedicine, lighter and stronger composites and textile and food industries.

Current and future research includes:

- Development of a better understanding of plasma processes and development of new plasma technologies and methodologies.
- Production and testing of new multifunctional nanomaterials for improved energy capture and storage.
- Application of liquid plasma techniques to milk & food sterilization while maintaining nutritional quality and allowing longer storage time.
- Application of liquid plasma technology in agriculture for plant growth and disease control.
- Application of plasma technology in fibrous and textile materials, composites and for solving industrial problems.

Top: Research at IFM aims to develop new polymer materials which will meet a diverse range of applications

Above: PhD student Andreas Kupke uses the Instron mechanical tester to perform tensile tests.

POLYMERS

Polymers are an essential element of modern life with many applications, including adhesives, coatings, paints, foams, composites, textiles, electronic and optical devices, and biomaterials. Through understanding fundamental principles in polymer science and technology, the Polymers Research group at IFM aims to develop new polymer materials which will meet a diverse range of applications. Current and future research areas include:

- Advanced thermosets for high performance coatings, adhesives and composites
- Polymer blends, composites and nanocomposites
- Biodegradable polymers for biomedical applications
- Green processing of natural polymers
- Rubber and plastics recycling
- Polymer materials for oil, gas and energy industry.

STEEL

Steel related research at IFM aims to address a number of key issues and challenges for the industry.

Steel is a heavy material for structures and is being challenged by a number of lighter weight structural materials. The response is to develop higher strength steels or steels with improved performance that can meet these challenges through control of the microstructure and processing route.

At the same time, opportunities also exist to produce steel strip using direct thin strip casting, which is a radical process change with the potential for massive reductions in energy and new products based around the unique process conditions.

The group's goal is to develop greener processes and products for a more sustainable and socially responsible steel industry through fundamental understanding and control over all length scales. Current and future research activities in the field include:

- Application of advanced high strength steel for light weighting in the automotive industry
- Development of strip casting technologies
- Application of advanced characterization techniques to understand strengthening of steels.

SURFACE ENGINEERING AND SURFACE PERFORMANCE

The surface of a material plays a crucial role in its performance. It is continually exposed to a range of wear conditions and corrosive environments, which determine the performance and life cycle of materials.

The performance of a material can be dramatically improved by the chemical or structural modification of its surface (surface engineering) or by alloy/thermal treatment design.

Improving the surface performance of materials can significantly contribute toward the key social challenge of the sustainable use of resources by reduced energy loss (friction/wear) or increased component/infrastructure durability. The group's aim is to understand the role of the surface in targeted applications to design novel alloys, thermal treatments and surface modifications, such as surfaces for extreme corrosion (e.g. desalination) and processing for high wear applications (e.g. the mining sector).

MEASURING OUR SUCCESS

By focusing on the goals and strategic priorities over the next five years, the objective is to achieve demonstrable increases in:

- New technologies in the marketplace
- Research grants and industry engagement
- Publications in high-quality journals
- The number of completions and quality of research students
- Citations
- Awards
- Collaborations
- Research reputation.

At a broader level, it is believed that IFM's research outcomes will add significantly to Deakin University's overall research performance and create new opportunities for the Geelong region.

Right: Vice-Director of Beijing Science and Technology Commission Mr GH Zhang, Chief Scientist of China Iron and Steel Research Institute, Prof S. Zhou, Deakin DVCR, Prof Lee Astheimer, and Prof Y Chen launched the Beijing Key Laboratory and the Deakin-CISRI Joint Research Centre for Energy Materials in Beijing.

STRATEGIC PLANNING PROCESS

This plan was developed through a consultative process which involved a series of half day workshops with the professoriate group and senior staff of IFM.

Information gathered from the workshops was distributed to key groups set up to refine and articulate the outcomes from the workshops, before being presented to the Executive of IFM.

On 30 August 2013, a Staff Planning Day was held to inform all staff of the IFM goals and associated strategies and seek their involvement in the development of realistic and feasible actions for the short, medium and long-term.

The Plan has been developed within the context of Deakin's Strategic Plan – *LIVE*.