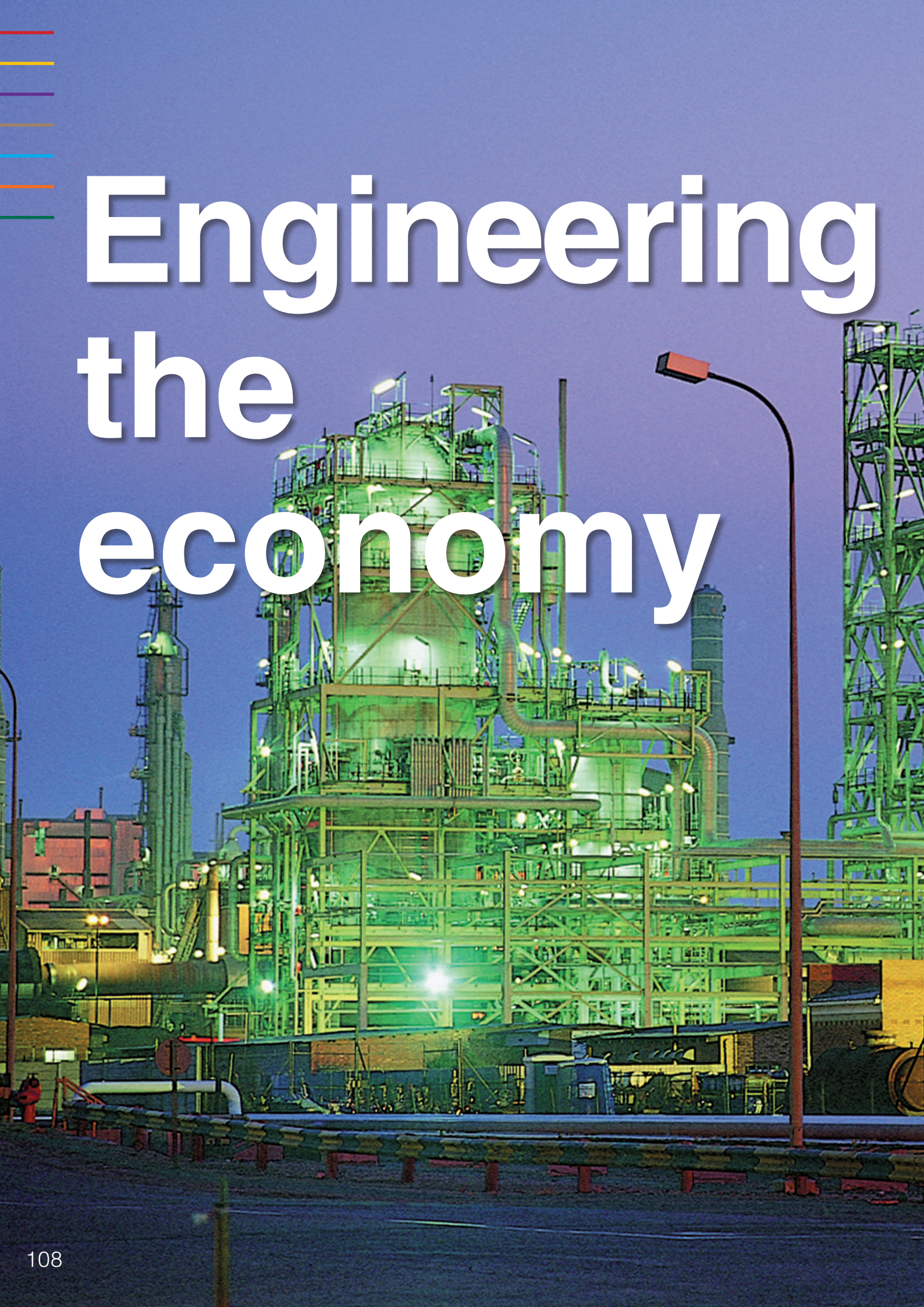
Engineering the economy



Holding around 75 percent of the world's known reserves and resources of platinum group metals or PMGs, South Africa has a commanding position in the world economy. Now, researchers at UCT are working to capitalise on these natural advantages, by promoting and developing value-adding processes, within the constraints of environmental concerns, and shift the country from a resource-based to a knowledge-based economy.

From resources to knowledge: the quest to transform South Africa's economy

In 2007, Minerals to Metals (M2M) was established as one of five signature research themes at UCT. The aim of the project was to integrate and expand capacity in minerals beneficiation research by drawing together the skills of world-renowned academic and research staff within four research groupings in the Department of Chemical Engineering, the Department of Physics, the Positron Emission Particle Tracking (PEPT) Research Group, and the Centre for Research in Computational and Applied Mechanics (CERECAM).

What makes Minerals to Metals so unique is that researchers focus on entire minerals processing flow sheets or production sequences (a systemic approach), as well as on individual mineral extraction processes, explains director, Professor Jean-Paul Franzidis, who holds the DST/NRF SARChI Chair in Minerals Beneficiation.

"Being the biggest mining economy on the continent creates opportunities. We are able to undertake research that would be difficult to do in other African universities."

"This means that we do research across the spectrum, from increasing the amount of mineral or metal extracted from ores, to reducing the environmental and social impacts of mineral beneficiation operations."

The signature theme, for example, oversees projects that explore reducing the acid-rock drainage from mine discards or tailings; examine the human factors that result in injuries and fatalities in mining; and investigate the potential for solar energy to power some mining processes, so as to reduce the sector's environmental footprint, among other things. The initiative's location in South Africa – and UCT – offers further benefits.

"Being the biggest mining economy on the continent does create opportunities," says Professor Franzidis. "For example, we are able to undertake research that would be difficult to do in other African universities, due to a lack of facilities. We attract many postgraduate students into our programme from other African countries, and this allows us to share the message of what we do all over the continent."

In addition, Minerals to Metals is also developing a new master's degree in Management of Mineral Resources for Sustainable Development in Africa, collaborating with the University of Zambia, as part of the Education for Sustainable Development in Africa (ESDA) programme of the United Nations. The new degree will include courses offered by the UCT Graduate School of Business and the Sustainability Institute at the University of Stellenbosch.

Time for a c*change

The DST/NRF Centre of Excellence in Catalysis (or c*change) is another research grouping within the Department of Chemical Engineering that has put a strong focus on the development of the next generation of technologies and researchers.

Since its inception in 2004, c*change, hosted by the Centre for Catalysis Research, has established itself as a key player in the field of catalysis science – a critical industrial technology underpinning the South African economy. As such, it conducts and oversees valuable, large-scale and long-term research that focuses on tough problems with industrial relevance in South Africa. One such technology is the Fischer-Tropsch process, a catalytic process that converts coal and natural gas to liquid fuels, and currently provides 40 percent of South Africa's liquid fuels requirements.

It is vital, then, that South Africa not only reinforces its expertise in this area, but also builds on this, says director, Professor Michael Claeys.

The science fraternity is starting to take note. In 2011, Professor Claeys and UCT colleague, Professor Eric van Steen, were named as finalists in the 2010/2011 National Science and Technology Forum-BHP Billiton Awards. This for a collaborative project that led to the invention of a patented instrument known as an In-situ Magnetometer, which sprang from their research into Fischer-Tropsch catalysis.

*In-Situ X-ray Diffraction (XRD) cell invented by Professor Michael Claeys of c*change and Dr Nico Fischer.*

But more than that, c*change aims, as an explicit part of its mandate, to transform the face of research in this field by encouraging and supporting more young black and women researchers to enter the field. Its name – c*change – a pun on Shakespeare's sweeping metaphor for transformation – reflects this ambition.

Its goal is to develop a cohort of scientists, engineers, technologists, and academics who can cement the centre's and country's reputation as a world leader in the field of catalysis; and to achieve this, it is even prepared to go back to school!

In 2011, c*change initiated the compilation of a resource pack containing a teachers' guide, learner worksheets, videos, animations and posters to help teachers and learners with the new school Grade 12 Physical Science syllabus. Together with industrial sponsorship for printing and distribution, 57 workshops were held nationally, which were attended by 2 000 teachers, with a total of 5 600 resource packs being distributed to schools countrywide.

Thinking green

While growth and development of the economy, through strong research and investment in the next generation of researchers is vital to the future of the country, researchers at UCT recognise that this cannot come at the expense of sustainability. Working in a field that has long been considered the antithesis of sustainability means that scientists and engineers working alongside the country's major industries have to rethink their technologies and processes.

The Centre for Bioprocess Engineering Research (CeBER) is doing exceptional work in exploring 'greener' ways to extract metals in industrial processes. They are conducting research into the use of bacteria, or bioleaching; considered a cleaner process than traditional heap leaching, which uses a series of chemical reactions to extract minerals. Bioleaching is being tested as an alternative method for the recovery of metals such as copper, zinc, and gold from low-grade mineral ores, and also comes with low investment and operational costs.

UCT's Minerals to Metals researchers do work across the spectrum from increasing the amount of mineral or metal extracted from ores to reducing the environmental and social impacts of mineral beneficiation operations.

Various studies at CeBER are in progress that will lead to a more thorough understanding of the behaviour of microorganisms within the heap bioleaching process.

"To create a bio-economy, we need to understand what happens at a microbial level," says CeBER director, Professor Sue Harrison, who holds the DST/NRF SARChI Chair in Bioprocess Engineering. "To get there, we need to grow the commercial bioprocessing space."

In addition to its bioleaching and hydrometallurgy activities, CeBER has, for the past six years, homed in on the energy potential of algae. This research, sponsored by SANERI (the South African National Energy Institute) and industrial partners, has identified algae as a multipurpose energy source.

Professor Harrison says that through the biorefinery concept, algae not only have the potential to provide economically valuable compounds such as antioxidants and speciality oils, but can also serve as an alternative source for protein, bio-diesel, and electricity.

"It is this marriage of developing value-added technologies and environmental stewardship that will enable South Africa to deal with issues such as efficient water and energy use."

It is this marriage of developing value-added technologies and environmental stewardship that will enable South Africa to deal with issues such as efficient water and energy use, Professor Harrison says. And this, she adds, hinges on South Africa's ability to develop and train the people who would be expected to put together and run bioprocesses.

With some 31 postgraduate students on the books, CeBER is well on its way to developing the know-how, and to ultimately disseminate to industry its scholarly prowess.

Signature theme associated with this theme

Minerals to Metals

The Minerals to Metals project boosts research on minerals beneficiation – the sequence of processes that produce metal from low-grade ore – from two main perspectives. The first focuses on underlying scientific areas within minerals beneficiation.

The second – systemic – approach considers the entire extraction chain to improve process performance, minimise the use of water and power, cut back on waste, and promote cleaner production options and technologies, as well as inherently safer process design. The theme integrates research in the Centre for Minerals Research, the Bioprocess Engineering Research Unit, the Crystallization and Precipitation Research Unit, and the Environmental Research Group.

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Centre of excellence associated with this theme

DST/NRF Centre of Excellence in Catalysis, c*change

The DST/NRF Centre of Excellence in Catalysis, c*change, is hosted by the Centre for Catalysis Research at the Department of Chemical Engineering. In 2011, the c*change team comprised 49 postgraduate students (of which 80 percent were from South Africa, with 55 percent and 67 percent of the local student target being female and black, respectively), nine postdoctoral researchers, and nominally 25 academics from 15 research groupings in 10 participating South African higher education institutions. A total of 21 projects were funded during the course of 2011, of which 13 were multi-institutional and/or inter-disciplinary projects.

In addition, c*change has contributed funding for proof-of-concept work on Direct Liquefaction of Micro-algae Biomass, a so-called c*STAR Project that forms part of a larger Micro-algae to Energy initiative. The concept of a c*STAR Project is to utilise the c*change network and resource capacity to demonstrate proof-of-concept projects, with a view to helping c*change and its members attract outside interest or funding for technology development projects.

The CoE has been awarded a SARChI Chair, which is expected to boost the scientific output of the centre. The Research Chair is located in the field of preparation and characterisation of nano-materials and will enhance various activities throughout the centre. The centre embarked on an extensive international search to find a suitable candidate, and an appointment is expected to be made in 2012.

The centre's strong involvement in the successful development of teaching material for the new school Grade 12 Physical Science syllabus was a highlight in 2011. The new syllabus requires learners to study the chemical industry in South Africa, with particular emphasis on the manufacturing of petrochemicals and synthetic fuels, chlor-alkali derivatives, fertilisers and batteries. As such, c*change initiated the compilation of a resource pack containing a teacher's guide, learner worksheets, videos, animations and posters. Together with industrial sponsorship for printing and distribution, and involving 18 organisations (universities, NGOs, education departments and private sector organisations), 57 workshops were held nationally, attended by 2 000 teachers, with a total of 5 600 resource packs being distributed to schools countrywide. The material is available to the public on several websites.

c*change held its seventh annual Symposium in November 2011 in Johannesburg and will be hosting a c*change Autumn School and the c*change Syngas Convention in 2012. c*change was also invited to participate as a co-organiser of the European Federation of Catalysis Societies (EFCATS) Summer School in The Netherlands, a result of considerable efforts in recent years to establish stronger international relations.

Competence centre associated with this theme

■ DST Hydrogen Catalysis Competence Centre, HySA/catalysis

The Department of Science and Technology's National Hydrogen and Fuel Cell Technologies Flagship Project, colloquially referred to as Hydrogen South Africa, or HySA, was derived from the National Hydrogen and Fuel Cell Technologies Research, Development and Innovation Strategy. The national flagship project established three competence centres in 2007 to develop hydrogen and fuel cell catalysts and catalytic device technologies, with a view to enhanced national wealth creation via value addition to South Africa's strategic reserves of platinum group metals.

The Hydrogen Catalysis Competence Centre (HySA/catalysis) is co-hosted by UCT and Mintek. Overall (15-year) deliverables comprise the development of hydrogen fuel cell and fuel processor technologies and intellectual property sufficient for the establishment of commercial manufacturing activities within South Africa, whether attracted from abroad or grown from inside the country. Further, enabling deliverables of HySA/catalysis are the establishment of research, development and innovation facilities for fuel cell and fuel processor technologies via an extended hub and spoke network comprising national science councils, universities and private enterprise, and the development of a significant human capital base.

With the appointment of Dr Olaf Conrad as the centre's Programme Director from 1 January 2011, the centre has sharpened its competency in fuel cell electrochemistry and electrocatalyst preparation. An initial group of five postgraduate students at master's degree level has been accepted into the programme and will be joined by another four students at the beginning of the 2012 academic year. This complements the longer-established activities in fuel processing with three current master's degree students at UCT and a further four students on HySA projects at the University of KwaZulu-Natal. Local and international expertise has been added with Dr Qiling Naidoo as a postdoctoral research fellow in the middle of 2011, and the successful recruitment of Dr Sharon Blair from Canada. Dr Blair will lead the key programme: Portable Power Systems of the HySA programme and will add her technical and business expertise.

Additionally, a high-calibre technical steering committee has been established, comprising experts from South African industry (Eskom and IST Powertech) and academia (Mintek and UCT), as well as international academia (Paul Scherrer Institute, Switzerland).

International research network activities now include student exchange and research collaborations with colleagues at Zentrum fuer Brennstoffzellen Technik Duisburg, Germany, the South Dakota School of Mining and Technology, USA, the Paul Scherrer Institute in Switzerland, and Imperial College London, UK.

Developing a clean-power economy

Whether it's the more efficient use of the Earth's dwindling natural resources – as CeBER is engaged in – or developing new technologies to improve processes, such as the Fisher-Tropsch process, there are others in the engineering faculty who have put these concerns at the front and centre of their research agendas as well. Nowhere is this better illustrated than in the bid to develop cleaner power.

By now, scientists and policy makers have come to accept that, in finding an alternative to fossil fuel, there may well have to be more than one option. Consensus appears to be that the world of the future will be run on a mix of green technologies, such as wind and solar power.

"South African industry has to learn to add value later down the production chain."

Hydrogen is seen by many as an integral part of that future. More importantly for UCT engineers, all related technologies, including hydrogen production, hydrogen storage, and electricity generation from hydrogen, are very likely to use platinum group metals.

In recognition of the future role of hydrogen, the Department of Science and Technology launched the Hydrogen and Fuel Cells Technologies Flagship Project – or HySA – in 2008. This national project aims

Research groupings associated with this theme

Centre for Bioprocess Engineering Research

The Department of Chemical Engineering has been known for its interest in bioprocess engineering for more than three decades. Following the formalisation of this research area through the establishment of a UCT research unit in 2001, the activity was upgraded to the Centre for Bioprocess Engineering Research (CeBER) in 2008, in recognition of the range of researchers active in this area, the contribution to research across several interlinked foci, and its role in the development of human capacity in this field. CeBER aims to underpin the growth and exploitation of the biological sciences in South Africa through a national centre of expertise in bioprocess engineering, in which the balance between research centred on the fundamental understanding of biological processes at the mechanistic level, the interaction of these processes with their environment and the application of biological principles to bioprocesses of economic, social, and environmental importance is maintained. This is underpinned by CeBER hosting the DST/NRF SARChI Chair in Bioprocess Engineering. The multi-disciplinary team brings together expertise in reactor studies, process modelling, biokinetics, microbial ecology, microbial metabolism, biotransformation, micro- and molecular biology, and biohydrometallurgy to develop detailed understanding of bioprocess systems. CeBER's key foci include biominerals engineering for the extraction of metals, as well as the prevention and remediation of metal-rich effluents, bio-transformation for value addition, bioprocess optimisation through metabolic modelling, reactor modelling, mass transfer optimisation, product liberation and recovery, bioprocess integration, and the role of the bioprocess in sustainable processes.
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Centre for Catalysis Research

The Centre for Catalysis Research concerns itself with both fundamental and applied research and development in the general field of heterogeneous catalysis – encompassing all of catalyst synthesis, physico-chemical characterisation and performance evaluation for industrially interesting chemical conversions. The principal fields of investigation include Fischer-Tropsch synthesis, zeolite/acid catalysis (especially as applied to hydrocracking and the transformation of phenols and derivatives) and catalysis by platinum group metals and gold. In addition, the Centre for Catalysis Research is the host laboratory for the DST/NRF Centre of Excellence in Catalysis (c*change) and the DST Competence Centre in Hydrogen and Fuel Cell Catalysis.
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Blast Impact and Survivability Research Unit

The Department of Mechanical Engineering has been involved in impact dynamics for over 25 years. In particular, research has focused on experimental and computational techniques to provide solutions for blast and structural impact scenarios. The Blast Impact and Survivability Research Unit (BISRU) has developed experimental facilities, which include a blast chamber, a selection of drop testers, material characterisation systems, and a sled tester for impact biomechanics. This collection of equipment is unique in that no other university laboratory worldwide has this full suite of facilities in one area. The research activities are aimed at promoting the study and understanding of impact dynamics through projects at senior undergraduate level and master's, doctoral, and postdoctoral levels. The research objectives are to reduce the risk of injuries and save lives through fundamental principles of science and engineering, using experimental, analytical, and computational tools and techniques to understand the mechanics, and dynamics of blast and impact loads. BISRU currently has several international interactions through collaborative projects with universities in Australia, Argentina, Europe, and the USA.
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Centre for Research in Computational and Applied Mechanics

Profiled on page 96.

Crystallization and Precipitation Unit

Profiled on page 78.

Research groupings associated with this theme

Concrete Materials and Structural Integrity Research Unit (CoMSIRU)

The Concrete Materials and Structural Integrity Research Unit has been developing technologies and procedures for the design and assessment of concrete structures for more than 20 years. The unit has had a marked focus on infrastructure performance and renewal, largely in response to industry needs. The key areas of interest are service life prediction, deterioration science, assessment technologies, and repair/rehabilitation strategies for concrete structures. CoMSIRU provides consultancy and postgraduate teaching in the areas of concrete material technology, concrete durability, structural health monitoring, and rehabilitation.
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Centre for Materials Engineering

The Centre for Materials Engineering strives to educate and train students in techniques and fundamentals in the broad field of materials engineering. It also seeks to serve a wide range of engineering activities, giving advice concerning material processing, properties and performance, while maintaining an international profile for its research. The research activities of the centre are aimed at addressing national needs in terms of both the provision of technological solutions and the development of skilled graduates.
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Centre for Minerals Research

The Centre for Minerals Research is a multi-disciplinary, interdepartmental research centre based in the Department of Chemical Engineering. The focus of research is on the processes of comminution, classification, and froth flotation, arguably the most important unit operations in minerals beneficiation. The primary objective of the centre is to investigate the above research areas at both an industrial (applied) level and at a laboratory (fundamental) level, so as to develop predictive models for describing the performance of industrial units and circuits. In addition, the centre sees as a priority the provision of high-level human resources to the South African mining and mineral processing industry through the production of high-quality postgraduates. The centre enjoys excellent international collaborations with all of the world's leading mining companies.
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Centre for Research in Engineering Education

The Centre for Research in Engineering Education, established in 1996, focuses on research in engineering and tertiary science education. The centre recognises that an engineering degree programme is not restricted to engineering subjects alone, but includes tertiary mathematics, physics, and chemistry. The aim of the centre is to develop theoretically informed and research-based ways of understanding the learning environment and the educational process, with a view to improving student learning and success in engineering and tertiary science. The centre has additional objectives of building capacity among academic staff to conduct education research in engineering and related disciplines, disseminating the results of this research, building the fields of engineering and tertiary science education research, and promoting regional, national, and international co-operation among education researchers in these disciplines.
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Sasol Advanced Fuels Laboratory

The Sasol Advanced Fuels Laboratory (SAFL) was set up in 2002 to actualise Sasol's future-oriented fuels research relating to combustion and emissions from automotive and aviation engines. The focus of the Sasol Advanced Fuels Laboratory is on medium- to long-term synthetic-fuel applications research. Research work entails the study of combustion in engines, and it ranges from the study of current synthetic fuels in current engines to future fuels and future engine concepts.
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DST/NRF SARChI Chairs associated with this theme

Catalysis

The DST/NRF Centre for Excellence – c*change – has been awarded a SARChI Chair in Catalysis, which is expected to boost the scientific output of the centre. The chair, which has not yet been filled, will be created in the field of preparation and characterisation of nano-materials and assist various activities throughout the centre, with the expectation that this will provide a mechanism of bringing the research of c*change to the level of world-class excellence.

Bioprocess Engineering

Professor Susan Harrison was appointed to strengthen her contribution to an integrated approach to optimisation and modelling of bioprocess systems and sub-processes for use in bioprocesses for economic, environmental and social benefit. The research programme centres on the establishment of generic knowledge at the molecular and metabolic, unit operation, and the sustainable process levels, for benefit across specific bioprocesses. These contribute across water treatment, human health, minerals beneficiation, resource productivity and renewable resources. Professor Harrison has actively enhanced the university's footprint in bioprocess engineering research, through expanding the group of researchers working in the field, enhancing the research infrastructure and the capacity to conduct research and train students as well as through knowledge generation.

Professor Harrison's group is viewed as one of the top four internationally in mineral bioleaching, among the most respected in algal biotechnology in South Africa, and she is well recognised for her bioprocess engineering expertise.

Minerals Beneficiation

Professor Jean-Paul Franzidis has been involved in mineral processing research for more than 25 years. In the 1980s, he led a research programme funded by the National Energy Council investigating the poor flotation characteristics of South African coals. In 1996, he joined the Julius Kruttschnitt Mineral Research Centre (JKMRC) at the University of Queensland, Australia, to lead the world's largest collaborative mineral processing research project, the AMIRA P9 project.

In 2007, Professor Franzidis returned to UCT to direct the newly formed Minerals to Metals Signature Theme and in 2008, he was awarded the SARChI Chair in Minerals Beneficiation.

to establish South Africa as one of the few nations that export high-value products into the growing international hydrogen and fuel cells markets.

HySA/Catalysis, based at UCT and co-hosted by Mintek, is one of three HySA Centres of Competence that have been mandated by the South African government to develop the competency, skilled workforce, and ultimately the manufacturing industry in South Africa.

"The major economies – the USA and Canada, Europe, and Japan – are leading by about 20 years, so the HySA programme's first objective is to leapfrog the technology development and prepare for commercialisation when the markets begin to grow," says HySA/Catalysis Director, Dr Olaf Conrad.

As with Minerals to Metals and CeBER, the South African industry has to learn to add value later down the production chain, adds Dr Conrad.

"The mandate of HySA/Catalysis, in keeping with that of the DST, is that South Africa should build the competence base to create products that are home-grown. And so bring investment to South Africa by setting up businesses that use our mineral wealth to create higher, value-added opportunities."

Whether it's improving on existing processes or exploration the next generation of green technologies, researchers across the university are pushing the envelope. If they get it right, South Africa will soon be recognised as more than just a wellspring of minerals, but also a true modern economy.