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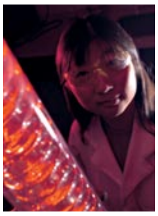

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CSIRO

CSIRO research in minerals processing and metal production JUNE 2006

PROCESS

LIGHT METALS

Time for titanium processing

By WHITNEY MACDONALD

TECHNOLOGY with the potential to halve titanium production costs and streamline processing could create an opportunity for Australia to finally manufacture the titanium it mines.

Australia has some of the most significant resources of titanium ore in the world, yet due to costly and complex processing methods, it lacks an associated titanium metal production industry.

However, cutting-edge technology developed by the Light Metals Flagship – an initiative combining the efforts of scientists from CSIRO and industrial research partners – could provide the capacity for local titanium production.

Titanium metal is extraordinarily strong and exceptionally lightweight – as strong as steel with only 60 per cent of the weight – and is bio-inert and resistant to corrosion. However, expensive and complex processing costs are only tolerated by the aerospace and biochemical industries, where the advantages of using titanium outweigh the expense. Other industries would greatly benefit from titanium's characteristics, but mostly fall just short of balancing the cost-benefit equation.

TiRO™, the new titanium processing technique developed by flagship researchers, is based on some of the same principles as the Kroll process – the traditional method for producing titanium metal – but is continuous and eliminates many of the middle steps, reducing production costs.

Like the Kroll process, TiRO works by reducing titanium tetrachloride with magnesium to produce titanium metal. However, unlike the Kroll process, TiRO occurs within a temperature window that makes it appropriate to use fluidised bed technology. It exploits the principle that when suspended in a gas, solid particles behave like a fluid and react more rapidly. The result is a titanium powder, produced from a much smaller reactor in a fraction of the time. Minimal waste is produced during the process.

CSIRO researcher Dr Grant Wellwood with titanium and titanium glasses. Lowering the cost of production could boost titanium's use in non-aerospace applications. PHOTO: CHRISTIAN PEARSON

Grant Wellwood, a senior process engineer leading the TiRO project, says the Kroll process generates a lot of waste and is also very expensive. "The current processes associated with titanium metal are very inefficient. Compounding the metal production

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Process

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COMMENT

DR BART FOLLINK
CHIEF, CSIRO MINERALS

Breaking through

An important part of CSIRO Minerals' mission involves working on immediate industrial challenges and applications. It tests our alignment with current industrial needs and it also provides us with a means to deliver instantaneous 'added value'. I am pleased to say that as a division, we are performing well in this regard.

Our research program structure, led by our experienced program managers, provides us with a proven and effective means to interact with our key industry segments. As the first point of contact, they are well-placed to manage and deliver both the contacts and project outcomes necessary to address the needs of the minerals industry. Yet, our ambitions also extend past the immediate horizon. Supporting today's industry is important; longer-term thinking and vision are crucial. This is particularly so for an organisation like ours. Our key stakeholders expect us to help secure a vibrant future for the industry by generating breakthroughs and enabling step changes. This demands leading-edge science.

Our science capabilities, both in a quantitative and qualitative sense, are crucial here. What do we need to do to ensure our key science areas deliver optimal future impact? (See also Open Space on page 11.) What sciences must we cultivate – for today and for tomorrow – to service industry and society? On the one hand, this requires a concerted capability planning process, based on a deep knowledge of relevant scientific developments. To this end, CSIRO Minerals has recently implemented a capability leadership framework, which includes nine capability leaders with clearly defined accountabilities for a specific area of minerals-relevant science.

It is this unique matrix of capabilities and programs that will drive the creation of longer-term industry impacts and options.

A deep knowledge of the industry's future direction is also necessary. I hope that the stories in this issue of *Process* will inspire you to share with us your longer-term strategic ambitions and directions. In this way, we can better direct the creative energy that is invariably generated whenever our programs and our capabilities intersect, to effectively meet the big challenges of the future.

Time for titanium processing

FROM PAGE 1

inefficiencies are those associated with downstream manufacturing."

For example, he says, it can take 10 kilograms of metal to produce one kilogram of manufactured product. "Although the waste is usually recycled, the rework cost is significant. In aerospace the ratio is even higher, with 'buy-to-fly' ratios of 15:1 common."

The Kroll process produces a 'titanium sponge', a coral-like substance that is an intermediate to the end product. This 'sponge' must be subjected to extremely high temperatures to melt it into a form that can then be shaped for various downstream applications.

"A more efficient approach for many non-aerospace applications is 'near net-shape' manufacture based on powder metallurgy," says Dr Wellwood. "However on a per-kilogram basis, the powders needed for this approach are currently more expensive than the sponge and even the finished products.

"So while titanium is a candidate for relatively inexpensive and well-established powder metallurgy techniques, the high cost of first producing the titanium in a powder form from the sponge route makes it unviable."

By directly producing titanium metal in the form of a powder, the TiRO process opens the door to using titanium rather than stainless steel, for more mainstream industries.

Titanium offers a particular advantage to the automotive industry: incorporating titanium into cars would mean a significant reduction in weight, translating to better fuel efficiency and environmental benefits.

The cookware industry is another area that could expect to reap the benefits from low-cost titanium production. With health concerns over certain types of cookware, manufacturers are looking for a material that offers the health-promoting trait of a non-stick surface without the associated complications. A reduction of about A$3 per kilogram in the cost of titanium metal could double the market for non-aerospace applications.

The flagship team is establishing a pilot plant that will operate at two kilograms an hour and build on the current proof-of-concept stage.

In conjunction with the International Titanium Association, the team recently held a 'Fundamentals of Titanium' workshop in Melbourne, Victoria, to promote the application of titanium.

Dr Wellwood says the outcomes were very positive, with a lot of government interest. "Everyone was very enthusiastic and supportive of the flagship titanium initiative; recognising that having a low-cost metal process is the key to setting up an industry in Australia."

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COMPUTATIONAL FLUID DYNAMICS

The plot thickens

By TONY KAYE

THE global surge in commodity prices, fuelled by massive demand from China and other countries, has cemented Australia's position as one of the world's leading mining nations.

However, as well as having the raw resources to meet demand, Australia's mining industry is at the leading edge of technology to maximise the efficiency and throughput of its operations. A major AMIRA research program into the thickening process used to separate minerals from ore slurry has already produced benefits worth hundreds of millions of dollars.

Through the Parker Centre, CSIRO has been working closely with industry to enhance processes in the thickener stage through novel modelling and experimental approaches, as part of the AMIRA P266 Improving Thickener Technology project.

One powerful tool is computational fluid dynamics (CFD), which uses advanced computer software to model the flow of fluids through a minerals processing facility. This allows variations in physical design and operational parameters to be tested to achieve the best possible performance.

CSIRO Minerals research scientist Tuan Nguyen says that since the project began in the late 1980s, the mining industry has achieved efficiency gains worth an estimated $295 million (net present value or NPV). In the longer term, gains are expected to exceed $500 million (NPV).

The team has successfully investigated ways of improving the performance of more than 100 thickeners, working with mining companies to achieve higher throughput, greater operational stability, enhanced overflow clarity, higher density in their underflows and lower flocculant consumption.

"Our work involves developing tools and knowledge to improve thickener performance for sponsoring companies," he says. "In the core research program, we do a lot of basic research developing tools like CFD models of key thickening processes. We use these tools to help companies with thickener problems."

Working on one-to-one projects with sponsoring companies, Dr Nguyen says CFD, coupled with experimental measures, has resulted in better solids dispersion, enhanced mixing and flocculation conditions, more even solids discharge, reduced flocculant use, greater operational stability, savings in water use, improved mill uptime, reductions in tailings, increased tails viscosity and improvements in overall tailings storage capacity.

The current phase of research, P266E, is supported by 20 Australian and international companies, including mineral processing operators from most commodity sectors, equipment manufacturers and chemical suppliers.

The overall vision is to enhance full-scale thickener performance and downstream processes by refining and expanding concepts and applying skills to new thickener technology issues.

"We've been looking at thickeners all across the minerals industry, covering sectors such as alumina, base metals, gold and minerals sands," Dr Nguyen says. "Wherever thickeners are used, we can help.

"CFD is a very common tool nowadays and a lot of people are trying to do the same thing. But our advantage is the multidisciplinary team we have, comprising chemists, engineers and fluid dynamicists.

"Essentially, we can get the chemical data from our experimental work and put that into our CFD models. Our models are based on realistic systems – that's why we are leading the world in the development of new thickener technology."

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Fifth CFD conference confirmed

Australia will host the Fifth International Conference on CFD in the Process Industries in December. It will focus on the application of CFD in the mineral processing, metal production, power generation, chemicals, food, oil and gas and other industries.

The conference aims to provide a forum to:

- explore the breadth and application of CFD modelling in the process industries;
- identify and report on emerging CFD capabilities and applications; and
- identify limitations in the existing CFD capabilities and validation sources.

The conference will promote and advance the application of CFD in mining. Papers will be presented on coal combustion, hydrocyclones, casting, fluidised beds, smelting, furnaces, slurries, steelmaking, crystallisation, stirred tanks and granular flow.

Confirmed keynote speakers include Dr Megan Clark (BHP Billiton), Professor Suhas Patankar (University of Minnesota), Professor Mark Kendall (University of Queensland), Professor Jan Cilliers (Imperial College) and Professor Li Jinghai (Chinese Academy of Sciences). The conference will take place in Melbourne from 13 to 15 December.

FOR MORE INFORMATION
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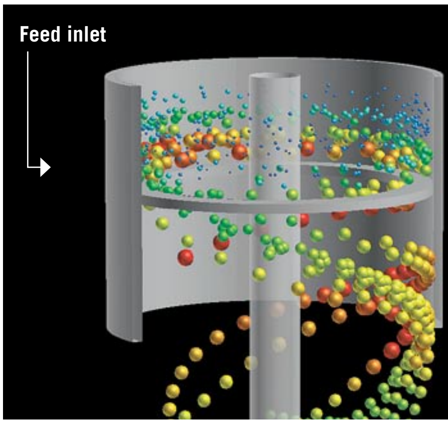

This CFD image shows particle aggregation in a feedwell.

Key points

- Thickener performance is critical when adequate overflow clarity or underflow density cannot be achieved at the required throughput or at acceptable cost
- Modelling – using CFD – can help improve thickener performance
- The AMIRA P266 Improving Thickener Technology project has achieved efficiency gains of $295 million (NPV) to date

SUSTAINABLE SINTERING

Forests the future for 'greener' steel

PHOTO: PHOTOLIBRARY.COM

By JULIAN CRIBB

IN the quest for cleaner fuels and reductants the spotlight has been thrown upon a major new resource – oil mallee trees and other Australian hardwoods – which could help industry produce a 'green' steel.

Products from plantations – such as those grown in Western Australia to help combat salinity – include oils, solvents, particle board, quality timber, electricity and activated charcoal, yet another major opportunity exists in producing charcoal for iron and steelmaking, say CSIRO Minerals' David Langberg and Roy Lovel.

Charcoal is highly reactive and, compared with coke, is very low in pollutants such as sulfur, nitrogen and ash, says Mr Lovel, who has been involved in testing charcoal for sintering iron ore. It burns faster, making the sintering process more productive, enabling sinter plants to keep pace with blast furnace demands.

Best of all, it is greenhouse-neutral: carbon dioxide liberated in the sintering process is absorbed by successive crops of growing trees.

"Charcoal production used to be thought of as a dirty industry, but nowadays it can be produced hygienically in as little as five minutes," says Mr Lovel. "Wood char can be used directly in sintering, where our research indicates it can be more effective than coke."

Oil mallees are not the only sources of char for making metal – farm and forestry wastes of various kinds, sawmill waste, paper and cardboard, biosolids, weeds and scrap building materials are all possibilities. And char can be used as an alternative to coke and coal in a range of metallurgical processes such as slag fuming, bath smelting, synthetic rutile production and ore sintering.

Dr Langberg says mallee charcoal performs as well as coal as a reductant in small-scale tests simulating the molten metal and slag bath process such as that used by HIsmelt. "It has the same advantages as in sintering – low sulfur, nitrogen and less ash. Even when you take account of the energy used in growing, processing and transportation, you still produce around 65 per cent less carbon dioxide for every tonne of iron.

"Potentially, bath smelting processes for ironmaking could run entirely on charcoal as the fuel and reductant, achieving a dramatic reduction in the environmental impact of ironmaking."

The chief obstacle towards its use is cost, he says. "Two years ago charcoal was more than twice the cost of coal. But coal prices have risen and, as mallee plantings grow, the price of char may fall. Also we are now using 'cheaper cuts' – the leaves and twigs of mallee trees – to reduce the cost."

The work on mallee charcoals is a collaborative effort between CSIRO, the Centre for Sustainable Resource Processing, the WA Department of Conservation and Land Management, and the CRC for Plant-based Management of Dryland Salinity.

Although WA has the biggest oil mallee industry, similar opportunities are opening up in New South Wales, South Australia and Victoria. Regional centres such as Port Pirie, Werribee and Port Kembla could be potential sites for charcoal metallurgy, as they combine agriculture and forestry industries and smelters that can use the char.

Another opportunity lies in the compound pellets of iron ore and carbon that are needed for the new direct reduction ironmaking processes.

Charcoal can also be used as an additive in electric arc furnaces and, by injection as a pulverised fuel, even replace up to 20 per cent of the coke used in a blast furnace, in order to reduce greenhouse emissions from conventional ironmaking.

Iron and steel are not the only opportunity for biomass char, Dr Langberg says. "We've also found considerable advantages in using charcoal as an iron reductant in the rotary kilns used for processing synthetic rutile. Charcoal should enable the furnace to operate at a lower temperature and achieve a higher throughput – both positive advantages."

Key points

- Trees planted to combat salinity could provide a new fuel source for making iron and steel
- Using biomass charcoal creates a greenhouse neutral process as carbon dioxide liberated in the iron-making process is absorbed by successive crops of growing trees

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ON-LINE ANALYSIS

Outokumpu signs on

THE LFM Moisture Analyser has broken new ground in terms of accuracy and reliability during trials at Outokumpu's ferrochrome pelletising plant in Tornio, Finland.

The plant is part of the world's largest stainless steel manufacturing complex with an annual capacity of 1.7 million tonnes of hot rolled stainless steel and 1.2 million tonnes of cold rolled steel.

In November last year, Outokumpu began trials of the CSIRO-developed LFM Analyser. The aim was to enhance the cost-effectiveness of the company's award-winning operation through full integration of the system in the plant's production chain.

Petri Jokinen, technology development manager at Outokumpu Technology, says: "Pelletising has a very critical moisture level to achieve optimum results. In the LFM Moisture Analyser we found a reliable instrument that delivers accurate moisture measurements for the control of our pelletising operations."

The company undertook extensive evaluation trials which involved remote calibration and verification of the analysers' outputs on 290 sample measurements. The analysers provided consistent accuracy (± 0.081 per cent one standard deviation).

Graeme McGown, managing director of Intalysis (the company spun out to commercialise the analyser), says the analyser's capability complemented Outokumpu's existing technology, ensuring the success of the trials.

"We knew that the LFM had the ability to achieve new standards of accuracy," Mr McGown says. "At Tornio it all came together – grade control was very good and process control led to very steady loading on their conveyer belts."

Outokumpu Technology has signed an Original Equipment Manufacturer (OEM) agreement with Intalysis on the basis of the trial results, and the analyser's flexibility and ease of integration with other on-line instrumentation. The Finnish company will now integrate LFM Analysers into its new pelletising plant deliveries.

Reliability is a key concern for the company, which operates and installs plants throughout the world.

"When establishing new technology such as a pelletising plant in a new country it is critical that you have instrumentation that can substitute for the black art found in established plants," Mr Jokinen says. "In the LFM Analyser we found a reliable instrument that can provide accurate moisture readouts for pelletising control."

As a result of the trials, Outokumpu Technology also now acts as a distributor of LFM Analysers for Intalysis in pelletising applications.

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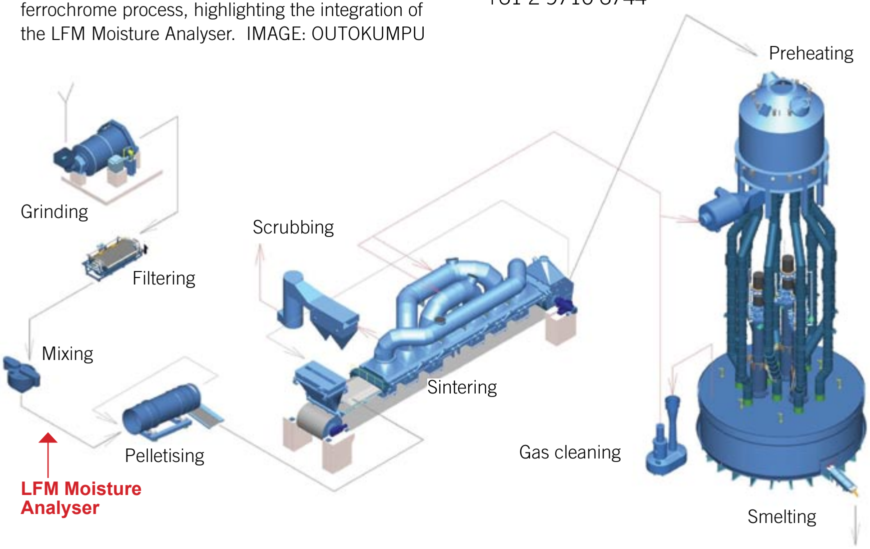

Flow sheet of the award-winning Outokumpu ferrochrome process, highlighting the integration of the LFM Moisture Analyser. IMAGE: OUTOKUMPU

Samples

A little SQUID, a lot of ore

CSIRO Industrial Physics has developed a highly portable geophysical exploration tool called LandTEM, to help mining companies locate ore deposits that conventional technology is unable to see. Based on Superconducting Quantum Interference Device – or SQUID – technology, LandTEM involves extremely sensitive magnetic sensors that detect large and highly conductive deposits of minerals such as nickel sulfide, gold and silver, which create problems for conventional coil magnetic sensors. The device has already helped unearth large deposits of nickel sulfides and silver worth hundreds of millions of dollars.

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ARTWORK BY PAUL DICKENSON, COURTESY OF SOLVE

Researchers gather to advance ionic liquids

Researchers interested in the development of novel compounds for applications ranging from separation science to electrochemical devices gathered recently at the Second Australian Symposium on Ionic Liquids in Melbourne. Sponsored by CSIRO, the Australian Centre for Electromaterials Science (ACES) and the Centre for Green Chemistry, the symposium covered all aspects of the chemistry and application of ionic liquids. Keynote speakers included Professor Ken Seddon Professor (Queens University Ionic Liquids Laboratory (QUILL)), Professor Robin Rogers (University of Alabama), Dr Frank Endres (TU Clausthal) and Dr Anna Prodi-Schwab (Degussa Creavis).

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IONIC LIQUIDS

Cutting aluminium energy bills: DESIGNER SOLVENTS

By BIANCA NOGRADY

IN an age of rising energy costs, technology that can help to reduce power consumption is critical. For Australia's aluminium producers, whose energy costs account for up to 15 per cent of the nation's electricity bill, research into 'designer solvents' might offer one answer.

Designer solvents, or ionic liquids, have the potential to cut aluminium production's energy needs by up to 30 per cent, potentially benefiting a range of industries from battery production to nuclear power.

The key to ionic liquids' power is their low melting point. Aluminium is currently produced through electro-deposition, where the alumina is dissolved in a molten cryolite bath at 1000°C and an electric current applied to separate aluminium from oxygen. The high temperatures needed to keep the cryolite liquid consume large amounts of energy.

In contrast, ionic liquids typically melt below 100°C. Used in place of molten cryolite, they could significantly reduce the energy needs of aluminium production.

The Light Metals Flagship is working with mining company Rio Tinto to develop an ionic liquid, which could cut costs and lower greenhouse emissions.

Ray Shaw, Rio Tinto technology support general manager, says that although research on ionic liquids is still in its early days, it is a novel approach that the company is watching closely.

"There's a real target of trying to reduce electricity consumption by 20 to 30 per cent," he says. "Researchers in America have predicted that ionic liquids could achieve a 30 per cent reduction in electricity use for aluminium processing.

"Whether that's achievable or not is pretty uncertain at this early stage. If there's an opportunity to do it significantly better then we're interested in exploring it."

Theo Rodopoulos, research scientist in light metals production with CSIRO Minerals, says ionic liquids have huge commercial potential. "They've got a wide liquidus temperature range and high thermal stability, so you can operate at higher temperatures to improve reaction kinetics without decomposing the solvent."

Their negligible vapour pressure also eliminates the release of atmospheric pollutants and because less of the solvent

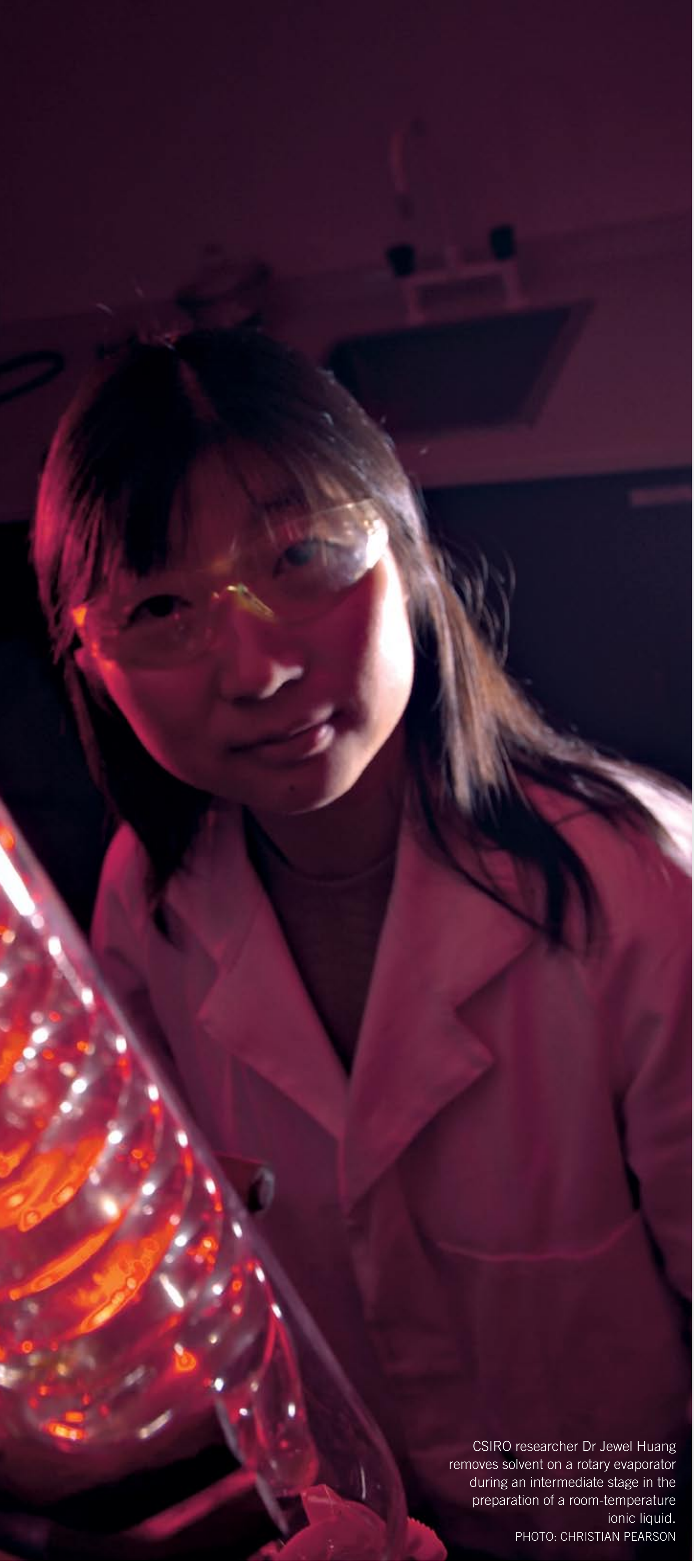
Key points

- Aluminium production accounts for about 15 per cent of Australia's energy consumption
- Research into ionic liquids could cut energy consumption by 30 per cent
- The key to ionic liquids' power is their low melting point, compared to solvents currently used to produce aluminium from alumina

What are ionic liquids?

Ionic liquids are a form of molten salt, but differ from traditional molten salts in ion size. Traditional salts such as sodium chloride consist of a small cation and small anion, which pack neatly together and form a solid.

However, in an ionic liquid, the cation is generally large and the anion is either large or small, resulting in poorer packing of the larger ions with weaker attraction, so the compound tends to remain liquid. It is this liquid state that is the key to ionic liquids' useful properties, which include high thermal stability, negligible vapour pressure and good electrochemical stability – making them attractive to any industry using solvents.



CSIRO researcher Dr Jewel Huang removes solvent on a rotary evaporator during an intermediate stage in the preparation of a room-temperature ionic liquid.
PHOTO: CHRISTIAN PEARSON

is lost to evaporation during processing, ionic liquids are more recyclable than conventional industrial solvents.

Ionic liquids' electrochemical stability gives them a significant edge over conventional aqueous and organic electrochemistry in the electrodeposition of certain metals, Dr Rodopoulos says. "For example, aluminium electrodeposition is not possible in water due to the reduction of water to hydrogen at the cathode."

They are often called designer solvents because they can be tailored to meet the demands of the application. Dr Rodopoulos says it all depends on what cation and anion are used, creating an unlimited number of combinations.

"I've seen 10^{18} being quoted," he says. "You really need to consider the sort of application you're interested in and choose your cations and anions accordingly to give you the desired properties such as lower viscosity, lower melting point or a particular solvation characteristic."

However, there are still issues to be resolved with ionic liquids – such as cost.

Dr Shaw says the challenge is one of scale. "You've got a challenge in that until significant quantities are used, the cost will remain high. So in that sense, they need to end up with a use that's sufficiently compelling so that it will drive someone to use it large-scale."

Dr Rodopoulos says that although ionic liquids are relatively easy to produce, they can vary greatly in purity. "They can be anything from colourless, which is typically what they should be, to pale yellow and brown, which is an indication of impurities." However, this may not be an issue if the impurities do not interfere in the ultimate application, he says.

The first ionic liquids were discovered in the early 1900s but their true potential has only begun to emerge in the past decade since the development of air- and water-stable ionic liquids. Aluminium processing is just one of many potential applications. CSIRO is also exploring their use as electrolytes in lithium batteries, as the organic solvents used in lithium battery manufacture are volatile and flammable.

Other potential uses include gas absorption, like carbon dioxide recapture in power plants, desulfurisation of fuels, dissolving spent nuclear fuel rods and even perfume production.

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ALUMINA PRODUCTION

Clearing the mud for the alumina industry

By YOUNA ANGEVIN-CASTRO

BY finding ways to treat and extract value from red mud, two CSIRO teams are working to improve the sustainability of the Australian alumina industry.

Through the Parker Centre in Perth, one team is investigating red mud disposal and re-use options, something a Melbourne-based team – in partnership with the Centre for Sustainable Resource Processing – is also researching via high-temperature processing.

Finding new options for red mud – or bauxite residue – is important given the amounts produced during the Bayer process, a chemical process used in the extraction of alumina from bauxite ore. Two tonnes of red mud are produced for every tonne of refined alumina extracted in Australia.

Annually in Australia, 30 million tonnes of red mud are produced, with about 80 million tonnes created worldwide. So finding new treatment and value-added processes could have major ramifications for the global industry.

Researcher Craig Klauber, who leads the Parker Centre effort, says residue is sent to purpose-built storage areas, which are "essentially above-ground residue mountains".

"These are well-engineered disposal areas designed both for some caustic recovery and for dust minimisation, but from an industry viewpoint, they are also intended as permanent repositories," Dr Klauber says. "We are looking at a number of aspects of the residue problem, including investigating and formalising the key issues of current residue management practices. There is little value in searching for future solutions if current storage practice is found to be deficient."

A Light Metals Flagship project involving CSIRO Minerals and CSIRO Land and Water is examining the suitability of bauxite residue components for remediating acid-polluted water as one re-use option, he says.

"A significant effort is also focused on understanding the chemistry of dust creation from existing residue disposal areas, to try and minimise the detrimental impact on the surrounding environment."

Meanwhile, Warren Bruckard, a metallurgist and leader of CSIRO Minerals' waste treatment team, is investigating the possibility of dealing with the red mud problem through high-temperature processing techniques.

"Our team is looking at using smelting to recover valuable by-products from the red mud," says Mr Bruckard.

He says handling red mud is problematic. "It's very fine, difficult to settle and filter and is highly alkaline. However, it also contains a range of valuable constituents, which we believe are worth attempting to recover."

The proposed smelting flowsheet includes extracting pig-iron, a soda and alumina-rich stream (which can be recycled back to the Bayer process) and a slag containing titanium, silica, lime, residual alumina and magnesium.

The slag phase is then further treated to produce a high-grade titania product plus a residue suitable as feed to a cement kiln.

"Basically, the integrated processes we are examining would convert a major problem into a sustainable zero-waste process."

The key challenge of this project is to ensure that during smelting the red mud components report to the appropriate phases.

"Once the process is optimised and validated at larger scale, we believe it has the potential to bring enormous economic and environmental benefit to the alumina industry," Mr Bruckard says.

Key points

- Red mud disposal and recycling options are being investigated by two CSIRO teams
- Australia produces 30 million tonnes of red mud or bauxite residue annually
- Although it is difficult to handle, there is potential to extract valuable products: pig-iron; a soda and alumina-rich stream; and a slag containing titanium, silica, lime, residual alumina and magnesium

Mandie Matheson conducting red mud leaching experiments.
PHOTO: CHRISTIAN PEARSON

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NANOTECHNOLOGY

Nano approach to Australia's big issues

APPLYING sophisticated mineral processing expertise to the burgeoning field of nanotechnology could help Australia become self-sufficient in liquid fuel and produce substances for mopping up heavy metals. To address the fuel challenge, CSIRO is proposing a project aimed at developing a continuous bulk process for producing materials coated with nanoparticles, using specialised pyrolysis and chemical techniques.

Alan Manzoori, process design and optimisation program manager at CSIRO Minerals, says: "Initially this project would focus on developing a novel, nano-coated catalyst for pyrolysis of Australia's stranded natural gas, helping Australia become self-reliant in diesel fuel."

Australia has large gas reserves, but diminishing reserves of crude oil. Most of the gas reserves are remote or offshore and many are considered commercially uneconomic or stranded.

"The proposed project would draw together expertise from CSIRO and our research partners in synthesis, characterisation, particle and reactor engineering, process chemistry, computational fluid dynamics modelling and catalyst testing," Dr Manzoori says.

In a second nanotechnology project, researchers are investigating the use of natural nanoporous materials in treating wastewaters.

In some ilmenites, for example, weathering has increased the surface area of the particles, creating many pores which may be able to selectively trap certain heavy metals. Natural nanoporous materials are an attractive alternative to custom-made ones as they are generally less expensive.

Dr Manzoori says these projects arose as CSIRO started exploring high-impact applications of its existing minerals processing scientific capabilities in the nanotechnology domain for areas specific to Australia's unique position.

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MATERIALS CHARACTERISATION

Australian OPAL to boost minerals science

The unique scientific discipline of neutron scattering is set to make a major contribution to Australian industry and science, as Australia's new nuclear research reactor, OPAL, comes on line later this year.

OPAL – run by the Australian Nuclear Science and Technology Organisation (ANSTO) – has neutron scattering instruments that will offer powerful tools to Australian and international researchers analysing matter. The instruments will be the world's best in some areas, such as time-resolved powder diffraction and small molecule crystallography.

Researchers hope to improve material processing and engineering by applying increased understanding gained from analysing the textural relationships, phase transitions, precipitation, defect mechanisms, thermal and dynamic recrystallisation and grain statistics of a material using neutrons.

"Neutron scattering allows more accurate characterisation of minerals and metals," says Klaus-Dieter Liss, of ANSTO's Bragg Institute. "I use neutron scattering to analyse thermomechanical deformation processes in titanium aluminium sheets."

The big advantage of using neutrons is the considerable depth to which they penetrate matter.

"In minerals, there are often heavy elements limiting X-ray access through the sample," says Dr Liss. "Neutrons are the obvious choice of investigative tool allowing for *in situ* studies, even in bulky environments.

"Although my background is in physics and metallurgy, investigations of texture, structure, phase composition and stress are relevant to geological processes and can be analysed using the same methods."

Ian Madsen, principal research scientist at CSIRO Minerals, is an advisory panel member for two OPAL instruments and has already reserved beam time at ANSTO. "We will be using the powder diffractometer to study the systematic structure variations in the iron ore sinter phase SFCA," says Dr Madsen.

"The techniques will complement our X-ray diffraction work. These new neutron scattering instruments will open up a world of opportunities for materials researchers."

Early experiments on OPAL's instruments will include texture measurements, with some conducted *in situ*. Australian scientists are invited to take advantage of the great potential these advanced new technologies offer.

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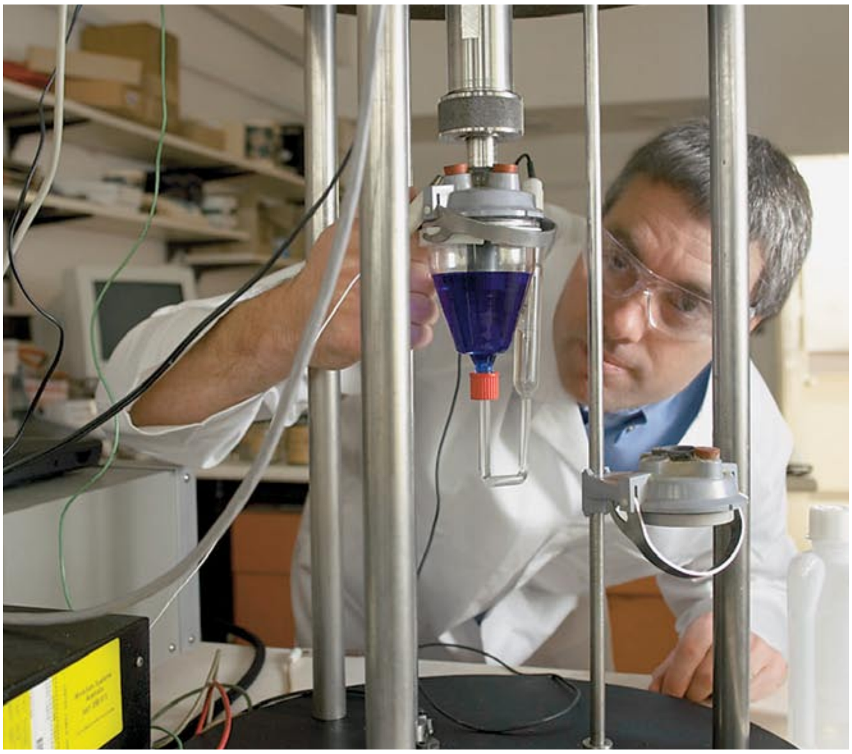
PHOTO: ANSTO

Powerful new tools: ANSTO's neutron scattering instrument, Echidna, with ANSTO's Dr Margaret Elcombe and Dr Klaus-Dieter Liss, and Dr Andrew Venter (right) from the SAFARI-1 neutron facility, NECSA, South Africa.

Thiosulfate shows potential for gold



Paul Breuer conducting gold leaching and electrochemical experiments using a rotating electrochemical quartz crystal microbalance. PHOTO: JAMES ROGERS

A LESS toxic alternative to cyanide for leaching difficult and environmentally sensitive gold ores is the aim of a series of Parker Centre projects.

Cyanide leaching is the dominant method of gold processing, accounting for more than half the world's gold production. It is a robust, relatively simple process that provides high gold recoveries, but poses potential safety and environmental risks in some situations.

Parker Centre researchers at CSIRO Minerals and Murdoch University are investigating thiosulfate, which is considered to be the best alternative to cyanide. Thiosulfate was first proposed as a way to recover precious metals in the early 1900s, but due to technical uncertainties it has never been adopted by the gold industry. The Parker Centre is working to resolve some of those uncertainties.

The chief advantage of thiosulfate – its non-toxicity – is currently outweighed by its disadvantages: the process is chemically complex, difficult to control and may result in slightly lower gold recoveries.

There are no thiosulfate systems in commercial operation, but interest in the technology is growing as gold producers encounter more refractory ores.

John Rumball, the Parker Centre's gold market leader, says: "Our understanding of the key parameters for thiosulfate leaching of gold is improving all the time. Although it is unlikely thiosulfate will universally replace cyanide, we can now see niche opportunities where thiosulfate offers significant advantages over cyanide. It is these niche applications where we are concentrating our research effort."

Niche opportunities include the processing of sulfide and carbonaceous ores and concentrates, from which thiosulfate can unlock gold more effectively than cyanide.

"We are currently working with a client to examine the feasibility of leaching a gravity concentrate with thiosulfate," says Dr Rumball. "The client is attracted to this opportunity as it would mean they would no longer require cyanide on their site. Replacing cyanide with thiosulfate would significantly reduce the hazards on the site."

Another niche application stems from the observation that some ores leach with unexpected ease. New work in this area indicates that ores can be conditioned to significantly improve their response in a thiosulfate leach. Dr Rumball says more details on this will emerge as the research progresses.

Paleochannel gold is another opportunity for thiosulfate leaching. Some of the paleochannel gold is hosted in porous sandstones that abut impermeable beds. This creates the ideal environment for solution mining. Solution mining involves pumping a solution underground to leach the gold, and then bringing that solution back to the surface to recover the gold.

This process removes the need to develop a large-scale, open-cut mine. Gold can be extracted from deep below without disturbing the surface. Thiosulfate is ideal for this application because of its low toxicity. The centre is generating a database that can be used to assess the feasibility of this process.

"Our focus is on understanding the chemistry that is likely to prevail in this environment," says Dr Rumball. "Leach times, solid solution ratios and oxygen availability are all very different to those in conventional stirred tank reactors. We need to get the leach conditions right if we are to dissolve the gold."

It is possible that either an iron-oxalate or an iron-EDTA oxidant system may have application in a thiosulfate leaching process. Parker Centre researchers are developing the iron-EDTA oxidant system for thiosulfate leaching of gold from ore and concentrates as part of the AMIRA P420C Gold Processing Technology project.

According to the Parker Centre, this process may be simpler to control and may provide more reproducible gold recoveries than the conventional thiosulfate system.

To complete the process, the Parker Centre has been undertaking research to recover the gold once it is dissolved in thiosulfate. Precipitation, cementation and resins are the key technologies available, with resins being the method of choice because of ease of operation. Although gold thiosulfate readily adsorbs onto resins getting it back off the resin has proven problematic.

"Exciting new research suggests this process is about to become a whole lot simpler," says Dr Rumball.

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LIGHT METALS FLAGSHIP

Electrowinning advances in inert anode technology

THE Light Metals Flagship is investigating new technologies to overcome environmental and operational difficulties associated with the use of carbon anodes in the light metals industry.

Asem Mousa, a research scientist at CSIRO Minerals, says there is a need to develop non-consumable anodes in light metal production, particularly within the aluminium, magnesium and titanium industries.

Carbon anodes are used in the electrolytic production of most light metals and the aluminium industry is the largest consumer of them. During metal production, anodes are consumed at a rapid rate and require changing about every three weeks. The replacement process is time-consuming and costly.

Dr Mousa says the use of inert anodes will reduce carbon monoxide and carbon dioxide gas emissions from light metal processing.

"Environmental issues such as global warming, ozone depletion and the greenhouse effect are all potential areas of concern in the future. Replacing carbon anodes with an inert (non-consumable) anode offers numerous environmental benefits."

The challenge for the flagship researchers is to produce anodes that remain operationally stable for months. They have already identified a promising candidate material for use as an inert anode in a magnesium electrowinning cell.

In a parallel project, CSIRO Minerals research scientist Kathie McGregor and her team have evaluated a range of candidate inert anode materials – including metals, alloys and conductive ceramics – for the electrowinning of titanium in a calcium chloride-based melt.

"Carbon has a great affinity for titanium metal, and there is a real risk of carbon contamination during titanium electrowinning," says Dr McGregor. "Our studies have examined the stability of other materials and their performance in laboratory-scale electrolysis tests."

Development of robust, oxidation-resistant materials that will bring cost-savings to light metal production processes is a continuing part of the flagship's research.

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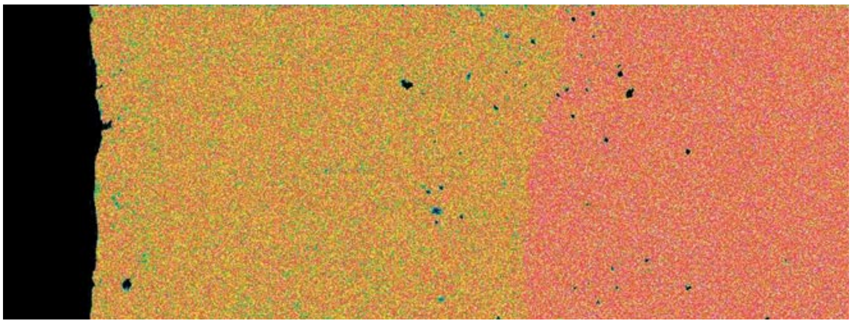
'inert anodes will reduce carbon dioxide and carbon monoxide emissions'

Electron microscopy image of an inert anode being tested for magnesium production.



Longer-term thinking needed

OPEN SPACE
DR IAN GREY
RESEARCH SCIENTIST,
CSIRO MINERALS

THE current research climate is increasingly driven by the need for quicker solutions to more intractable problems. This is particularly so in the minerals area, where urgent answers are needed to solve problems associated with extracting and processing lower-grade ores, while minimising environmental damage and reducing energy and water consumption.

The objectives appear to be almost mutually exclusive. Paradoxically, what is needed is longer-term thinking and research planning to effectively contribute to these short-term demands.

How can we increase the chances of fundamental research and frontier science leading to successful application in major industry and national problems? Serendipity plays a part, but to paraphrase Thomas Jefferson: "The harder we work the luckier we get." Although a focus on empirical short-term applied research is generally unlikely to yield the best solution to a complex problem, it is also true that fundamental research, conducted without exposure to real problems, is unlikely to be productive.

The ideal is having sufficient funding and people resources, either through National Research Flagships or industry partnerships, to support research teams working in parallel on both applied and fundamental aspects of the common problem.

Good communication between them is essential. The idea of 'roving' specialists in specific disciplines or techniques, who attend project meetings and advise where fundamental studies will build the in-depth knowledge needed to move forward, is also a good one.

This issue is timely in outlining some of the longer-term research that CSIRO and its partners are investing in to help industry in the future.

R&D: critical for future

LEADER'S FORUM
DR RAY SHAW
GENERAL MANAGER,
TECHNOLOGY SUPPORT,
RIO TINTO TECHNOLOGY

THE minerals industry faces many challenges: more complex orebodies, remote locations, increasing costs and the need to minimise impact on the environment. R&D is critical to helping us to improve our operations to address these.

Both the invention of new processes, technologies and equipment, and adapting existing technology and processes from other industries to fit our needs, require a strong R&D capability. This enabling role is often underestimated but is generally the larger source of industry changes, and means that R&D can deliver a great deal of value even if nothing 'new' is invented.

One example of the use of R&D and technology from outside the minerals-specific area is the benefits breakthroughs in material science have provided in the development of improved equipment. In an industry where crushing and grinding ores is a major component of work, equipment wear-and-tear is a big issue. This has both reduced the longevity of the equipment and also restricted our use of new, more efficient designs such as High Pressure Grinding Rolls (HPGRs), which were until recently restricted to softer materials.

HPGRs are now being installed in copper plants to give both energy and cost savings. The answer has not been to invent new equipment, but rather to incorporate developments in material science into existing equipment – a move that has been highly successful.

Likewise, the ability to mathematically model different processes has also been of huge advantage to our industry, especially in relation to aluminium, and this too can be regarded as a breakthrough in science. The ability to build larger, more efficient reduction cells has been highly dependent upon sophisticated computer modelling of the electrical and thermal characteristics of proposed designs. Similarly the new HIsmelt iron-making processing plant in WA has depended heavily on computer modelling.

A lot of the fundamental mathematics has come from NASA and the weather forecasting industry. The ability of good research providers, like CSIRO, to assist us to extract value from it and adopt the technology to our industry is critical. In the future, modelling will still form a large part of how we design and control plants.

Many of our goals can be achieved through this building on technologies from other sources but there are still challenges in front of us, which will need step changes in the technology used. This is especially true of our continued drive to minimise energy use, and to reduce the waste generated from extracting minerals.

Success in these will enable us to extract material currently deemed un-extractable, process material more economically, use fewer materials and create less waste. They will also address special issues from the remoteness of much of Australia's mining, which lends itself heavily to opportunities in automation.

What we have to be clever at is seizing fundamental science and inventions from across industries and the globe and assessing their worth to our industry. Doing this well is a critical and a major part of creating breakthroughs in our industry.

'Old economy': high tech, cutting edge

By MICHAEL WEIR
Senior Resources Writer,
The West Australian

DURING the dot.com boom not that long ago we were constantly being told that the resources industry was 'old economy'. Everything else was 'new economy' and that was the way the world was heading.

Well the dot.com bubble did not last and the world came to its senses, realising how valuable commodities were. And now we are in the middle of the greatest mining boom ever as countries like China and India strive to emulate our standard of living.

We regularly hear the criticism that Australia is fast becoming a quarry. Is that such a bad thing? If you are good at something shouldn't you just do it, and do it well? If our skills are in farming and mining, should we be that concerned if our coastlines are not full of steel plants and shoe factories.

Australia might well be a quarry but the very use of that word conjures up a fairly old-fashioned image. But if you take a look at mining (and farming too for that matter) what you see is a merging of that 'new economy' technology with our existing industries.

Australia's mining industry is the most high-tech in the world, with mind-blowing amounts of science, technology, computerisation, systemisation and automation.

The blending of technology with resources means our mines are more efficient, safer and environmentally friendly.

Exploration technology is helping find ore bodies in the most remote places, mining technology is keeping ore bodies alive longer, processing technology is helping make money out of previously marginal ore grades and environmental technology is successfully returning mined land back to its natural beauty.

This push toward technology too, is not lessening the requirement for people in the industry. The current skills shortage is evidence that to keep this industry at the forefront of global mining we need more people.

The skills shortage is now viewed as the key issue having a detrimental impact on both industry profitability and future growth prospects.

However, it is not just truck drivers that are in short supply. It was not that long ago that many out-of-work geologists were driving taxis in Perth to make a living. Now they are being snapped up before graduation, as are engineers, surveyors and other professionals.

It is not just in the field where more bodies are needed. It is vital to keep a flow of keen students taking up positions in research and technology because it is the science work at that embryonic stage coming out of our universities and research houses, like CSIRO, that will keep Australia the most high-tech quarry in the world.