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Message from the Director

It is essential to run alumina refineries efficiently to be profitable in this competitive business environment. Since the Bayer process is a mature technology, the low-hanging fruit of technical improvements have already been picked. To achieve further gains, a deep understanding of the process fundamentals must be established and used as a platform for targeted applied development.

The University of Queensland Rio Tinto Bauxite & Alumina Technology Centre is a team of dedicated staff and students working with industry advisors from Rio Tinto’s Queensland Research and Development Centre. We focus on high value opportunities that begin in the conceptual phase then progress through laboratory demonstrations to industry application. Our core capability is hydrometallurgy and we collaborate with experts from other disciplines such as minerals processing, pyrometallurgy and environmental management to address project specific challenges.

In 2016, our theme of bauxite impurities continued with the focus on high silica bauxite. Four graduate students joined the centre and five undergraduate students took part in the projects. The research effort was bolstered with Dr Hong Peng being awarded the Advance Queensland Fellowship.

We are now four years into the Centre and it is encouraging to see our efforts making an impact. Highlights include delivering a comprehensive suite of mercury analytical tools, developing an approach to control oxalate precipitation using low cost additives, and progressing new process options for high silica bauxite. This coming year will be an opportunity to reflect on the Centre’s performance and future plan in the context of a renewal of the mandate.

Please contact me regarding Centre enquiries.

Sincerely,

James Vaughan
Director – UQ RT Bauxite & Alumina Technology Centre
The University of Queensland | School of Chemical Engineering
Aims of the Centre

The aim of the Centre is to provide strategic support for Rio Tinto’s technical and process development, strengthening fundamental and applied research capabilities. The Centre offers educational and professional development pathways for current and future Rio Tinto employees.
Board of Directors

The Centre is governed by a Board of Directors that meets bi-annually with the Director to provide guidance on activities and strategy. The Board consists of Professor Peter Hayes Leader of the Metallurgical Engineering Program at UQ, Professor Peter Halley Head of the School of Chemical Engineering, Dr Anthony Canfell Manager Refinery Support, Bauxite and Alumina at Rio Tinto and Mr Andrew Horvat General Manager, Energy & Refinery Support, Pacific Operations, Rio Tinto.

PROF. PETER HAYES

BSc/MSc (Metallurgy) Newcastle on Tyne (UK) 1972
Ph.D. (Metallurgy) Strathclyde University (Scotland) 1974

Prof. Hayes is the University of Queensland Metallurgical Engineering program leader. He was founding Director of PYROSEARCH, the Pyrometallurgy Research Centre. The focus of PYROSEARCH is high temperature smelting and processing of metals, specialising in slag chemistry, and high temperature chemical reaction kinetics and mechanisms in ferrous and non-ferrous metallurgy. Dr Hayes is the author of over 300 research publications in international journals and conference proceedings.

PROF. PETER HALLEY

BEng (Chem) The University of Queensland (Australia) 1987
PhD (Chem) The University of Queensland (Australia) 1993

Prof. Halley is the Head of the University of Queensland School of Chemical Engineering. His research is in bio-based materials and polymers, and he operates at the translational research interface between universities and industry. He is a chief investigator in the Advanced Materials Processing and Manufacturing Centre, an affiliate professor in the Australian Institute for Bioengineering and Nanotechnology as well as a Fellow of the Institution of Chemical Engineers and the Royal Australian Chemical Institute.
ANDREW HORVAT

Andrew is part of Rio Tinto’s Pacific Operations Aluminium Division. He oversees Pacific Operations’ energy supply arrangements and technical support to its Gladstone refineries and overseas bauxite customer refineries. He has more than 25 years of experience in the mining industry in a variety of site and corporate-based roles spanning aluminium, coal, lead, zinc and iron ore. Prior to his current role, Andrew held roles as Vice President Business Analysis for Rio Tinto Alcan based in Montreal, and General Manager Business Development for Rio Tinto Aluminium based in Brisbane.

DR. ANTHONY CANFELL
Manager Refinery Support, Bauxite and Alumina, Rio Tinto.
BEng (Chem) The University of New South Wales (Australia) 1993
PhD (Chem) The University of Queensland (Australia) 1998

Anthony works for Rio Tinto Aluminium in the Pacific Operations Division and leads the Refinery Support team that provides centralised process engineering and R&D (QRDC laboratory) support to the Pacific alumina refineries. He has over 20 years of minerals processing experience with bauxite, alumina, magnesium and copper. His previous roles with Rio Tinto Aluminium were in refinery operations, process commissioning, engineering design, project management and corporate technical support. Anthony is the Chair of Alumina Quality Workshop (AQW) Inc. and is the Rio Tinto representative on the Alumina Technical Panel.
Staff and Academic Contributors

DR JAMES VAUGHAN
BEng (Metallurgy) McGill (Canada) 2001; MASc (Material) University of British Columbia (Canada) 2003; PhD (Materials) University of British Columbia (Canada) 2007
Centre Director

James is Senior Lecturer in hydrometallurgy at The University of Queensland. Over the past eight years at the University, he has contributed to research and development in precipitation, ion exchange and leaching. Before joining the University, James gained experience in industrial extractive metallurgy research and development with Placer Dome Mines and BHP Billiton.

DR HONG PENG
BEng (Minerals) Central South University (China) 2003; MSc (Bio-hydrometallurgy) Central South University (China) 2006; PhD (Flotation) The University of Queensland (Australia) 2013
Advance Queensland Research Fellow

Hong brings over 10 years of experience in the field of metallurgy and minerals processing which include bauxite flotation and novel industrial crystallisation processes. He joined the Centre in 2014, after obtaining his PhD degree on fundamental aspects of nanobubble formation. Hong’s Advance Queensland Fellowship focuses on process development for high silica bauxite.

DR WILLIAM HAWKER
BEng (Chem/Met) The University of Queensland (Australia) 2009; GCResComm The University of Queensland (Australia) 2012; PhD (Metallurgy) The University of Queensland (Australia) 2015
Associate Lecturer in Hydrometallurgy

Will has studied the mitigation of gibbsite-oxalate scale during precipitation through experimental investigations. His current research interests are bauxite residue sinter-leach, pressure oxidation of gold bearing sulphide ore, nanofiltration membrane separations and impurity removal from copper concentrate. He has developed new metallurgical processes for low-energy copper production and for streamlined refining of intermediate mixed nickel-cobalt hydroxide.

DR LIGUANG WANG
BEng (Mineral Processing) Central South University (China) 1998; MEng (Mineral Processing) Central South University (China) 2001; PhD (Mining and Minerals Engineering) Virginia Polytechnic Institute and State University (USA) 2006
Senior Lecturer in Minerals Processing

Liguang’s interests are froth flotation, solid/liquid separation, and gas hydrates. His research program is supported by the Australian Research Council, Australian Coal Association Research Program and industry partners. He is currently advisor on the bauxite residue particle-particle separation project.
JAMES GUDGEON

BEng (Chem/Met) The University of Queensland (Australia) 2010

Research Officer

James joined the Centre in early 2013 as a research officer after two years at the Queensland Research & Development Centre (QRDC), where he worked on Bayer organics control and residue management at laboratory and pilot plant scale. He provides research support, coordinates maintenance of research equipment as well as documenting procedures for the generation of quality data. He is also skilled in the development of customised programs for data processing and analysis.

DR TALITHA SANTINI

BSc (Environmental Science) Hons/BA University of Western Australia 2008; PhD (Soil Science) University of Western Australia 2013Queensland (Australia) 2015

Senior Lecturer in Environmental Management

Talitha is a Senior Lecturer in the School of Earth and Environmental Sciences at the University of Queensland. She has worked with the bauxite and alumina industry for nearly a decade, leading a research program focussed on the remediation and reuse of bauxite residue. Her research interests include mined land rehabilitation, environmental mineralogy and geochemistry, and microbial ecology and biotechnology.

VALENTINA URRUTIA GUADA

BSc (Biology) Universidad Simón Bolívar (Venezuela) 2007; MEnvMng The University of Queensland (Australia) 2012; GDipBus The University of Queensland (Australia) 2013

Laboratory Manager

Valentina is responsible for the deployment of safety systems in the hydrometallurgy and pyrometallurgy labs. During 2016, she was nominated to the UQ Awards of Excellence in Wellness and Safety, followed by a second nomination at the Faculty Awards for Outstanding Achievement in OH&S.

KELLY BYRNE

BEng (Chem) The University of Queensland (Australia) 2014; MPhil Student (Metallurgy) The University of Queensland (Australia) 2018 (expected)

Research Assistant

Kelly brings industrial experience to the team from her placements at the Rio Tinto Yarwun laboratories. Her project experience includes digestion, clarification and environmental issues. Kelly provides lab support for mercury assays, solution silicate assays and Bayer liquor analyses.
Graduate Research Students

DILINI SENEVIRATNE

BEng (Chemical)/ BSc (Microbiology) The University of Melbourne (Australia) 2007
PhD Candidate

Dilini has over 7 years of experience as a process engineer with Rio Tinto Copper and Coal, focusing on primary copper heap leaching Technology and Innovation. She joined the centre in July 2015 and her current research aims to manipulate Bayer desilication product crystallisation to enable separation of a concentrate.

NICK GHANE GHANAD

BSc (Materials) Sharif University of Technology (Iran) 2008; MASc (Materials) The University of British Columbia (Canada) 2011
PhD Candidate

Nick has more than 6 years of research and engineering experience in the mining industry in Canada and Australia. As a process engineer / metallurgist at SNC-Lavalin Australia in Perth, he was involved in numerous engineering design projects. Prior to this, Nick undertook his master’s studies at the University of British Columbia where his research resulted in a novel catalysed leaching method for treating enargite deposits.

HARRISON HODGE

BEng (Chem/Met) The University of Queensland (Australia) 2015
PhD Candidate

Before starting his PhD, Harrison completed two research internships on physical minerals processing at the University of Queensland Julius Kruttschnitt Mineral Research Centre. His current research looks at the recovery of sodium and aluminium from Bayer process desilication product and bauxite residue using a combined pyro-hydrometallurgical process.

JOHN VOGRIN

BEng (Chem/Met) The University of Queensland (Australia) 2015
PhD Candidate

John recently began his PhD research after four months as research assistant with the UQ Hydrometallurgy Group. His project aims to generate fundamental solubility data for a range of well-defined desilication products, which will lead into the development of a robust model.
STEFAN LAKEMOND
BEng (Chem/Met) The University of Queensland (Australia) 2012
MPhil Student

Stefan joined the Centre after working in the hydrometallurgy group as research assistant, developing a novel method for recycling platinum and palladium from automotive exhaust catalyst and improving cyanidation of gold flotation concentrates. His project is on crystallising large sodium oxalate particles from Bayer liquor.

CHRIS STAUN
BSc (IndChem) Central Queensland University (Australia) 2012
MPhil Student

Chris brings industry experience from his term at Queensland Alumina as well as servicing the technical and research needs for bituminous formulations. He has significant analytical experience, including method development and validation. His project focuses on stabilisation of mercury during the digestion process.

MAHENDRAN CHOKKANATHAN
BTech (ChemEng) Madras University (India) 2003
MPhil Student

Mahendran has more than 10 years of experience as a process engineer in various alumina and aluminium engineering projects. He has been involved in mathematical modelling and simulation of various facilities within the Bayer circuit for process and energy optimisation. Mahendran also has hands on experience in alumina refinery commissioning. His current research focuses on understanding the factors limiting bauxite residue particle-particle separations.
Undergraduate Research and Placement Students

The Centre facilitates Master of Engineering industry placements in conjunction with Queensland Research and Development Centre (QRDC) and the Gladstone refineries. Additionally, the Centre hosts undergraduate Research Scholars; promoting the advancement of the students towards a career in the bauxite and alumina industry.

*Students who have participated in learning programs through the Centre are as follows:*

**2016**
- Mengliu Ding (Undergraduate Thesis and Research Scholar)
- Matthew Iredale (Occupational Trainee, University of Bath (England))
- Lee Lumayag (Undergraduate Research Scholar)
- Nick Salmon (UQ BE/ME Industry Placement, QAL)
- Geoff Xu (Undergraduate Research Scholar)

**2015**
- Neetu Bansal (PhD Project)
- Calvin Chandra (UQ BE/ME Research Project)
- Wenting “Wendy” Du (UQ BE/ME Industry Placement, QAL)
- Benjamin Foster (Undergraduate Research Scholar)
- Weng Fu (PhD Project)
- David Johnson (UQ BE/ME Industry Placement, QRDC)
- Reza Salimi (PhD Project)
- Rico de Villiers (UQ BE/ME Industry Placement, QRDC)
- Benjamin Worley (UQ BE/ME Industry Placement, QAL)
- Chua Zhen Yee (Undergraduate Research Scholar)
2014
Michael Booth (Undergraduate Research Scholar)
Calvin Chandra (UQ BE/ME Industry Placement, QAL)
Jack Edwards (Undergraduate Research Scholar)
Chelsea Hayward (UQ BE/ME Industry Placement, QRDC)
Georgina Lehmann (UQ BE/ME Industry Placement, QRDC)
Damien Naidu (UQ BE/ME Industry Placement, QAL)
William Shipperley (Undergraduate Research Scholar)
Avanti Venkatesh (UQ BE/ME Industry Placement, QRDC)
Shay White (Undergraduate Research Scholar)

2013
Nabilah Mohamed Aroff (Undergraduate Research Scholar)
Adam Han Onn (UQ BE/ME Industry Placement, QRDC)
Michael Hart (UQ BE/ME Industry Placement, Yarwun)
Llyza Mendoza (UQ BE/ME Industry Placement, QRDC)
Jackson Moore (UQ BE/ME Industry Placement, QAL)
Luisa Prasetyo (Undergraduate Research Scholar)
Sue Ying Tang (Undergraduate Research Scholar, University of Melbourne)

L–R: Geoff Xu, Chris Staun, Dilini Seneviratne, Mahendran Chokkanathan, Jingwen Zhang, Jing Wei Hu, Ivana Ambrosia, James Gudgeon, Harrison Hodge, Kelly Byrne, John Vogrin, Lee Lumayag, William Hawker, James Vaughan, Peter Hayes, Liguang Wang, Weng Fu, Tiangui Qi and Hong Peng.
Capabilities

The Centre capabilities encompass laboratory and pilot scale equipment, experimental methodologies, solution and particle analysis as well as thermodynamic and process modelling. A key aspect of the Centre is the close collaboration with the Queensland Research and Development Centre, described as benchmark regarding industry-university collaboration. This results in seamless application of the research outcomes, infrastructure and knowledge sharing. The Centre's takes advantage of the extensive research infrastructure of the University of Queensland such as the Centre for Microscopy and Microanalysis and the Australian National Nanofabrication Facility.

A combination of Atomic Absorption Spectrometry, UV-Visible spectroscopy, liquor titration, and AccuSizer particle counting allows for a majority of sample analysis to be undertaken in-house. This is of particular importance for the multiple high silica bauxite projects, which demand rapid sample turn-around times for specialised procedures. Mastersizer, Coulter and Focused Beam Reflectance Measurement for particle sizing along with Inductively Coupled Plasma Spectrometry and Anion Chromatography are accessible through collaboration with the Queensland Research and Development Centre and through other sections of The University of Queensland.
This year, equipment and procedures for autocalve gas mercury analysis were developed using specialised sampling chambers, adsorption columns in combination with the Direct Mercury Analyser and Flow Injection Mercury System. This is complimentary to previously developed methods providing maximum flexibility in obtaining accurate mercury assays from Bayer solids, solutions, and gasses.

The ALExx rotating block heater donated by Queensland Alumina was commissioned and provides the capacity to run multiple 45mL digestion tests in parallel, making it the tool of choice for digestion scoping and optimisation studies as well as for the determination of equilibrium chemical thermodynamic data at Bayer digestion conditions.

Another capability development is In-situ X-ray diffraction using the high-resolution Rigaku Smart labTM diffractometer recently acquired by UQ. Now phase transformations can be accurately tracked as a function of temperature and time, up to 1100°C.
Projects and Outcomes

OXALATES PROJECT 1 (COMPLETE)

THE CO-PRECIPITATION OF GIBBSITE AND SODIUM OXALATE UNDER BAYER CONDITIONS

Dr. Weng Fu

Industry challenge
Sodium oxalate is generally present in bauxite, but most of the Bayer process oxalate is generated through degradation of organic impurities during the digestion stage. The limited solubility of oxalate in the Bayer solution results in co-precipitation of sodium oxalate and gibbsite during the precipitation stage leading to a wide array of operational, maintenance and production problems.

Technical Objectives
The main objective of this research was to understand, at the molecular level, the nature of the co-precipitation occurring between gibbsite and sodium oxalate in the Bayer process. This project consisted of three distinct focus areas: (1) the precipitation mechanism of sodium oxalate under Bayer conditions; (2) the interaction mechanism between gibbsite and sodium oxalate under Bayer conditions; (3) sodium oxalate-induced gibbsite secondary nucleation under Bayer conditions.

Skills developed
Technical communication skills, knowledge of operational practice, development of technical/experimental capabilities within the lab, e.g., crystallisation methods, electron microscopy, in situ optical microscopy and atomic force microscopy.

Achievements
PhD thesis, five journal and two conference papers published. Oxalate management strategies have been proposed to Rio Tinto based on the research findings.
OXALATES PROJECT 2

OXALATE CRYSTAL MORPHOLOGY MODIFICATION FOR THE BAYER PROCESS

Stefan Lakemond, MPhil Candidate
Advisors: Alistair Gillespie (RTA), Liguang Wang (UQ), James Vaughan (UQ)

Industry challenge

Organic matter in the bauxite feed for alumina plants introduces a range of process complications. As organics are degraded during digestion, sodium oxalate is generated which is of particular concern as it can have substantial impacts on product quality and forms a scale during the precipitation section of a Bayer process if the concentration becomes sufficiently elevated. Managing sodium oxalate formation often limits the caustic strength and temperature profile in the precipitation circuit, reducing productivity in order to maintain product quality.

Technical Objectives

Specific technical objectives of this project include: (1) developing experimental methods for studying oxalate nucleation and crystallisation processes at simulated industrial conditions, and (2) assessing process parameters that affect oxalate morphology and how this might be advantageously modified.

Skills developed


Achievements

Development of continuous stirred reactor experiment set-up and methodology which allowed sodium oxalate concentration to be increased in a supersaturated solution while other liquor components remained constant. Particle nucleation and evolution were monitored in-situ using the focused beam reflectance measurement probe. Using this approach, conditions were identified to produce large, homogenous robust sodium oxalate particles from industrial liquor.
MERGENCY PROJECT 1 (COMPLETE)

DETERMINATION OF MERCURY DEPORTMENT IN BAYER PROCESS & OPPORTUNITIES FOR ITS REMOVAL

Dr. Neetu Bansal

Industry challenge
Mercury is a toxic element present in bauxite at low concentration. In the Bayer process, a portion of the mercury is extracted from the solid phase and exits the refinery at multiple points in different forms. The industry is seeking a safe, effective and cost efficient method to isolate the mercury from the circuit.

Technical Objective
The primary objective was to develop methods to accurately determine the mercury content in the Bayer process streams to improve mass balancing efforts and to identify opportunities for recovery.

Skills developed

Achievements to date
Development of an accurate, sensitive and robust method to assay mercury in Bayer process solids resulting in preliminary refinery mercury mass balances and insight into the variation in the concentration of the toxic element. High level refinery mercury mass balances. Comparison of the electrochemical potential and pH conditions in Bayer liquor to mercury speciation and oxidation-reduction reactions.
MERCURY PROJECT 2 (COMPLETE)

STABILISATION OF MERCURY DURING BAYER PROCESS DIGESTION

Chris Staun, MPhil Candidate
Advisors: Irena Chandrawana (Rio Tinto) William Clarke (UQ), James Vaughan (UQ)

Industry challenge
Mercury is a bioaccumulative neurotoxin, present in bauxite at trace concentrations. As a result of the reducing digestion conditions in the Bayer process, volatile elemental mercury is formed. Gaseous evolution of mercury during liquor flashing results in partitioning to heat exchangers and solvation in condensate waters.

Technical Objective
The primary objective was to identify an additive which stabilises mercury to a non-volatile phase in digestion, preventing the deportment of mercury to condensate.

Skills developed
Chemical thermodynamics of gaseous and aqueous systems, with particular regard to aqueous activity of non-electrolytes. Instrumental analytical and development techniques. Academic writing and presentation.

Achievements to date
Sulfide and copper hydroxide were demonstrated as process additives for mercury stabilization. The performance of these additives was evaluated through direct analysis of gaseous mercury concentration in an autoclave digestion, imitating Bayer process conditions. Sulfide reduced gaseous mercury by an order of magnitude.

The chemical thermodynamics of elemental mercury in sodium hydroxide solution and the resulting Sechenov salt effect were evaluated. Geochemical speciation of mercury in bauxite was investigated in cooperation with the Spanish National Coal Institute, using sequential extractions and speciating thermal desorption technology.

A hydrofluoric acid total dissolution assay method was developed to determine mercury concentration in bauxite. Concurrent development of a thermal desorption methodology to determine mercury concentration in alkaline liquor has resulted in the capability for determination of mercury in all Bayer process materials.
SILICATES PROJECT 1 (IN PROGRESS)

INTEGRATION OF A MODIFIED PRE-DESILICATION PROCESS ROUTE FOR BAYER PROCESS

Dr. Hong Peng
Advisors: Warren Staker (Rio Tinto), James Vaughan (The University of Queensland)

Industry challenge
Processing high silica bauxite is costly to the Bayer refinery. This is due to loss of caustic soda for re-precipitation of dissolved silicates, higher neutralisation costs due to the presence of sodalite in the bauxite residue and precipitation of desilication product on heat exchanging surfaces increasing energy requirement and causing unwanted process downtime.

Technical Objectives
The aim of this project is to facilitate a technological breakthrough that will significantly enhance Queensland’s bauxite mineral reserves and support the potential to expand the alumina industry in the State. This will be achieved through the development of a new, innovative technology for the processing of existing bauxite mineral deposits; minerals that cannot currently be utilized because they contain high concentrations of deleterious reactive silica impurities.

Skills developed
In-situ high temperature X-Ray Diffraction (Rigaku and Synchrotron), Ultra-violet Raman Spectroscopy, Population Balance Modelling, scanning electron microscopy and transmission electron microscopy.

Achievements to date
3. Advance Queensland Research Fellowship (April, 2016).
SILICATES PROJECT 2 (IN PROGRESS)

CHEMISTRY ENABLED ENLARGEMENT OF BAYER DESILICATION PRODUCT

Dilini Seneviratne, PhD Candidate
Advisors: Warren Staker (Rio Tinto), James Vaughan (The University of Queensland), Hong Peng (The University of Queensland)

Industry challenge
Reactive silica in bauxite can cause unwanted scale formation and contamination of alumina product due to high levels of silicate in Bayer liquor. The presilication step, through the formation of crystalline aluminosilicates known as desilication product (DSP), is therefore an important step in silicate control. However, DSP precipitation also leads to the loss of caustic soda and aluminium, increased residue neutralisation costs and inefficient residue solid-liquid separation. It is proposed that if a concentrated stream of DSP can be separated from bauxite residue, it can be economically recycled to recover lost caustic and aluminium through the lime sinter-leach process. The ability to control crystallisation of DSP in the presilication and/or digestion stages, to increase the size of discrete DSP crystals and reduce intermingling of DSP with other mineral phases, would allow for an improved sized based separation. If DSP can successfully be separated from other residue minerals, significant caustic savings can be made, unlocking the ability to economically process high silica bauxite ores in the future.

Technical Objectives
This project aims to deliver DSP crystal enlargement by studying, the growth and agglomeration mechanisms of desilication product crystallisation under various conditions that can be manipulated in the presilication circuit. These are primarily, temperature, supersaturation, seed type/size, seed dose and shear rate. The use of crystal modifying additives will also be investigated to enhance this process.

Skills developed
Analytical techniques such as scanning electron microscopy, energy-dispersive X-Ray spectroscopy, Bayer liquor titrations, silica UV-Vis spectrophotometry as well as Mastersizer, Coulter Counter and AccuSizer particle size distribution characterization. Experimental techniques such as shaker flask and continuously stirred tank reactor crystallisation and autoclave preparation of synthetic Bayer liquors have also been developed.

Achievements to date
Preliminary DSP precipitation tests have shown that by varying process conditions both increases in individual crystal size and enhanced agglomeration can be achieved. Agglomeration may be key to the enlargement of DSP as 10 - 40 µm agglomerates were produced with seeding. These agglomerates were able to withstand lengthened sonication, indicating successful aggregate cementation. The addition of an anionic surfactant has also shown changes to product crystal morphology, individual crystal size and agglomerate size. The effect of bauxite residue minerals on DSP nucleation is currently being investigated.
CHEMICALLY MODIFIED BAYER PROCESS
DESILICATION

Nick Ghane Ghanad
Advisors: Warren Staker (Rio Tinto), Hong Peng (The University of Queensland), James Vaughan (The University of Queensland)

Industry challenge
The cost imposed by loss of soda in the Bayer process comprises a significant portion of the total cost of alumina production. Soda loss in the Bayer process happens when aluminosilicates known as desilication products (DSPs) are formed. The precipitates contain sodium in their molecular structure which is the source of caustic loss. The soda loss margin can increase when processing bauxite ores with higher amounts of reactive silica.

Technical objectives
One option to decrease the loss associated with formation of desilication products is to produce alternative DSPs with lower soda content (compared to conventional DSPs) using additives such as calcium. The objectives of this project can be placed in four categories: 1. Synthesis and characterisation of aluminosilicates in the present of an additive such as calcium, 2. Thermodynamic modeling of aluminosilicates formation in the presence of the additive, 3. Study the effect of impurities, and 4. Bayer circuit-related experiments.

Skills developed
Analytical techniques such as scanning electron microscopy, energy-dispersive X-ray spectroscopy, silica determination in Bayer liquor by spectrophotometry, Bayer liquor titration, AccuSizer particle size distribution analysis, autoclave operation for preparation of synthetic Bayer liquor.

Achievements to date
Assessment of the feasibility of precipitating low soda desilication products in the presence of chemical additives using bauxite.
Industry Challenge
As the most detrimental impurity found in bauxite, reactive silica represents a serious concern and must be controlled. The current methods for reactive silica removal in the Bayer process involve precipitation of a sodium alumino-silicate phase (DSP). This results in loss of both alumina and the valuable sodium reagent used in the Bayer process. As the Australian minerals industry steadily depletes bauxite reserves low in reactive silica, the average reactive silica grade of available Australian bauxite increases. As reactive silica levels rise, the cost of the current silica removal processes increase, decreasing refinery profit margins. To offset this cost a methodology for the recovery of lost caustic and alumina from the bauxite residue must be developed. A promising method to achieving this is the bauxite residue sinter-leach process.

Technical objectives
This project aims to investigate key issues surrounding the implementation of the sinter-leach process into the traditional Bayer circuit. This will include the investigation of the impact of variable residue composition, processing a high quality DSP concentrate and linking sinter product morphology and composition to downstream leach performance.

Skills developed
Scanning electron microscope, optical microscope, Bayer liquor titrations and atomic absorption spectroscopy. Continuously stirred and shaker reactor tests for assessing the leachability and overall recovery of sinter products.

Achievements to date
Sinter-leach tests were conducted producing baseline data and the skillset needed to move forward. Preliminary investigation into the morphology of the sinter product has been undertaken as well as qualitative and quantitative assessment of mineral phases before and after sintering. This has revealed the basic reactions and reaction pathways during the residue sintering process.
Industry challenge
Reactive silica from bauxite ore reacts with caustic to form desilication product (DSP) in the Bayer process. This DSP is discharged from the process and maintained in long term storage facilities, along with the other impurities. As DSP contains sodium and aluminium and alkalinity, it would be beneficial to re-process DSP to recovery these elements, however, recycling processes are not efficient if the DSP concentration is too dilute. Therefore, a physical concentration step for the DSP would be desirable. The first challenge in separating the DSP from bauxite residue is that discrete DSP particles are less common than DSP which is intermingled or associated with other minerals. The second challenge in physical concentration is the fine size of DSP, which is less than 5 μm.

Technical objectives
The main objectives of this project are: (1) to establish a relationship between the different Bayer process conditions and their influences on the minerals association with the DSP and (2) to assess the key reasons and intermolecular force or energy between the DSP and other associated minerals.

Skills developed
Experimental technique, mastering instrumental analysis, synthesis and analysis of results, fundamentals of Bayer processing scenarios as well as technical communication skills.

Achievements to date
A mathematical model was developed to estimate the solid and liquor assay, for bauxite processed in various process conditions in the laboratory. Methodology development to identify the DSP in the samples and to quantify iron minerals associated with it using cryogenic scanning electron microscopy. Poster presentation at the Australian X-Ray Analytical Association Conference in Melbourne (Feb 2017).
TRICALCIUM ALUMINATE PROJECT (COMPLETE)

CRYSTALLISATION OF TRICALCIUM ALUMINATE (TCA) AS FILTER AID

Dr. Reza Salimi

Industry challenge

The on-site generation of tricalcium aluminate as the Bayer liquor filter aid and operation of filters constitutes a major operating expense for alumina refineries. Inconsistent filter aid quality can dramatically increase the frequency of filter cleaning, reduce filter productivity and can even compromise alumina product quality if certain insoluble impurities (calcium, vanadium, iron, silica) are able to pass through the filters. While many empirical optimisation studies have been completed, the fundamental basis for selection of conditions is not always apparent and the approach can vary widely across refineries.

Technical objectives

Determine the solubility of tricalcium aluminate over a range of industrially relevant conditions. Develop a mechanistic model of the crystallisation process from batch experiments by studying the changes in both the solution and solid phases. Relate the batch crystallisation process to the continuous crystallisation using chemical engineering theory. Generate well-defined tricalcium aluminate from the continuous reactor at select conditions. The new information on solubility, metastability, nucleation and crystal growth mechanisms will provide guidance on improved design and control of the tricalcium aluminate crystallisation process which ultimately controls liquor filtration performance.

Skills developed

Material characterisation, experimental design, fundamentals of thermodynamics and statistics, attention to detail, managing risks to work safely, experimental troubleshooting skills, technical presentation and writing skills.

Achievements

Development of methods to assay trace levels of calcium in solution and accurately determine particle size distribution from kinetic and lime conversion from kinetic samples. Tricalcium aluminate solubility as well as batch and continuous crystallisation reveal the particle formation reaction pathway and effects of key process parameters.
Research Output

Journal Publications


Conference Publications


Theses


Communications

In addition to formal publications, Centre activities and outcomes are disseminated through industry reports, presentations, knowledge exchange events, quarterly updates, the annual report and the website. Key Centre events are summarised in the annual timelines below.
## Financial Report

<table>
<thead>
<tr>
<th>Expenditure</th>
<th>2013 $’000</th>
<th>2014 $’000</th>
<th>2015 $’000</th>
<th>2016 $’000</th>
<th>2017 $’000</th>
<th>2018 $’000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Staff</td>
<td>156</td>
<td>341</td>
<td>358</td>
<td>272</td>
<td>288</td>
<td>TBD</td>
</tr>
<tr>
<td>Admin</td>
<td>15</td>
<td>16</td>
<td>17</td>
<td>18</td>
<td>19</td>
<td>TBD</td>
</tr>
<tr>
<td>Travel</td>
<td>6</td>
<td>12</td>
<td>13</td>
<td>10</td>
<td>10</td>
<td>TBD</td>
</tr>
<tr>
<td>Projects</td>
<td>0</td>
<td>90</td>
<td>180</td>
<td>370</td>
<td>406</td>
<td>351</td>
</tr>
<tr>
<td>Contingency</td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>30</td>
<td>TBD</td>
</tr>
<tr>
<td>Capability Development</td>
<td>19</td>
<td>19</td>
<td>25</td>
<td>10</td>
<td>10</td>
<td>TBD</td>
</tr>
<tr>
<td>Total</td>
<td>196</td>
<td>478</td>
<td>593</td>
<td>680</td>
<td>763</td>
<td>TBD</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Revenue</th>
<th>2013 $’000</th>
<th>2014 $’000</th>
<th>2015 $’000</th>
<th>2016 $’000</th>
<th>2017 $’000</th>
<th>2018 $’000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Centre Funds</td>
<td>294</td>
<td>314</td>
<td>336</td>
<td>360</td>
<td>385</td>
<td>TBD</td>
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<tr>
<td>RT Projects Funds</td>
<td>0</td>
<td>90</td>
<td>180</td>
<td>237</td>
<td>237</td>
<td>218</td>
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<tr>
<td>UQ/State Government</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>133</td>
<td>133</td>
<td>133</td>
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<tr>
<td>Carry Over</td>
<td>-</td>
<td>97</td>
<td>24</td>
<td>-53</td>
<td>-3</td>
<td>25</td>
</tr>
<tr>
<td>Total</td>
<td>294</td>
<td>501</td>
<td>540</td>
<td>677</td>
<td>788</td>
<td>TBD</td>
</tr>
</tbody>
</table>

| Surplus (Rev. - Exp.) | 98 | 23 | -53 | -3 | 25 | TBD |