Self-review report

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Centre for Materials Engineering
Department of Mechanical Engineering

Prepared by
Thorsten H. Becker

With contributions from
James Dicks,
Sarah George,
Sherlyn Gabriel,
Robert Knutsen, and
Penny Louw

Summary

The Centre for Materials Engineering (CME) at the University of Cape Town (UCT) research spans various materials, emphasising the relationships between processing, structure, properties, and performance. Significant research areas include additive manufacturing, focusing on developing advanced materials like titanium alloys, nickel-based superalloys, and shape memory alloys to enhance additive manufacturing technologies. Research on aluminium works closely with industry partners to improve aluminium processing, particularly for beverage cans and automotive applications, and explores computational and machine learning techniques to optimise aluminium alloy properties. In sustainable materials research, the Centre explores bio-based materials for high-impact and blast-resistant applications to contribute to safer and more environmentally friendly engineering solutions.

CME offers a BSc(Hons) in Materials Science, combining coursework with practical research to provide students with theoretical knowledge and hands-on experience. The program has successfully integrated graduates into academic and industrial careers, reflecting the Centre's commitment to developing the next generation of materials scientists and engineers. Notably, the BSc(Hons) is a strong feeder for our MSc and PhD studies in materials engineering.

The Centre strives to create a collaborative and inclusive environment emphasising interdisciplinary research and high-impact outputs. The mission is to maintain its leadership in materials science and engineering in South Africa by advancing knowledge, supporting industry competitiveness, and promoting sustainability. The Centre fosters interdisciplinary collaboration with academia, industry, and government to address complex materials-related challenges. Future goals include strengthening partnerships with industry to ensure that research and education remain relevant and impactful. The Centre is committed to enhancing the understanding of materials science and engineering, driving innovation, and contributing to societal and environmental benefits through its research and academic programs.

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1 INTRODUCTION

1.1 Background

The Centre for Materials Engineering (CME) at the University of Cape Town (UCT) began as the Department of Metallurgy and Materials Science in 1972 under the leadership of Professor Tony Ball. Originally a member of the Mechanical Engineering Department, Professor Ball's research quickly gained attention from UCT management, leading to the expansion of materials science and engineering expertise at the university. In addition to contributing to the Mechanical Engineering undergraduate program, the new department focused on developing postgraduate students at the MSc(Eng) and PhD levels.

The department expanded rapidly, establishing comprehensive capabilities in mechanical testing, microstructure characterisation, film processing, and machine shop support within a newly constructed, purpose-built space. Additional academic staff joined the department, and research flourished with robust support from sponsors such as the Chamber of Mines Research Organization, Middelburg Steel and Alloys, Hulamin, De Beers Diamond Research Laboratories, and Boart Longyear. The high demand for research led to the launch of an undergraduate BSc(Eng) program in Materials Engineering in 1983 to strengthen the pipeline of postgraduate candidates. In 1984, the department formally changed its name to the Department of Materials Engineering and received full accreditation from the Engineering Council of South Africa (ECSA) and the Institute of Materials (UK).

In the late 1990's, UCT began to streamline its departments and faculties, resulting in the merger of the Department of Materials Engineering with the Department of Mechanical Engineering in 2000. Materials-focused research became the strongest research activity within the Mechanical Engineering Department, leading to the establishment of the Centre (CME) under the leadership of Professor Rob Knutsen. After serving as Director for 22 years, Professor Knutsen stepped down, and Associate Professor Thorsten Becker assumed the role of Director in January 2022.

Since CME's inception in 2000, it has maintained a robust research agenda at the postgraduate level, achieving significant milestones and strategic expansions. The Centre has played a pivotal role in supporting government-led advanced manufacturing technology strategies. Historically, CME has been instrumental in advancing research in light metal alloys, which received substantial support due to its alignment with national priorities. Research on novel platinum alloys gained momentum, facilitating further exploration in this field. Additionally, CME assumed a leadership role in developing the Eskom Power Plant Engineering Institute's (EPPEI) Materials and Mechanics Specialization, a project central to advancing materials engineering in the energy sector.

More recently, CME has focused on additive manufacturing through the government-led Collaborative Program in Additive Manufacturing, initially concentrating on titanium alloys and later expanding to a broader range of materials, including nickel-based superalloys, precipitation-hardenable aluminium alloys, and shape memory alloys. CME has also enjoyed strong support from industry partners in its research focused on the aluminium industry in South Africa with endorsement from the Aluminium Federation of South Africa (AFSA). The Centre's research portfolio has further diversified by introducing biobased polymers and composites, a new area of focus supported by funding from the National Research Foundation (NRF) and internal UCT funding mechanisms.

It is also worth highlighting the BSc (Hons) Materials Science program hosted within CME, which has been offered as a postgraduate degree for over 20 years. This unique program in South Africa typically admits candidates with a BSc degree in Chemistry, Physics, Geology, or Biochemistry. The program has provided an inclusive approach to the various disciplines of Materials Science, combining coursework with a laboratory-based research project. It offers candidates valuable exposure to CME's research activities and industry associations, equipping graduates with the theoretical and practical skills necessary for further postgraduate studies or careers in the Materials Science and Engineering industries.

CME also serves the university in various materials-related research topics across multiple departments. It supports its sister Centres, such as BISRU and CERECAM, and contributes to research efforts in its department and other departments, such as Civil Engineering. Additionally, the Centre collaborates with faculties, including the Faculty of Science and Health Sciences, to advance interdisciplinary research initiatives.

In 2022, CME celebrated its 50th anniversary, marking a significant milestone in its history.

1.2 Mission

The mission of CME is to advance Materials Science and Engineering by supporting human capital development through postgraduate degrees and cutting-edge research that explores the intricate relationships between process, structure, property, and performance across various materials. We are dedicated to supporting the competitiveness and sustainability of South African Materials Science and Engineering, particularly in the manufacturing industry, by developing capacity and expertise while also providing innovative solutions and translating research findings into practical applications that benefit society and the environment.

We foster interdisciplinary collaboration with academia, industry, and government to address complex materials-related challenges while providing high-quality education and training to develop the next generation of Materials Scientists and Engineers in South Africa and beyond. We are committed to promoting inclusivity by attracting and nurturing diverse talent and ensuring equitable opportunities within the field.

Through our research, we aim to develop human capacity by actively engaging postgraduate students and collaborating with local and international research partners, industry stakeholders, and government initiatives. CME also plays a vital role in supporting the Mechanical Engineering and Mechanical and Mechatronic Engineering programs within the Department, offering infrastructure and expertise to advance these disciplines.

1.3 Who we are

Our core activities can be split into two trajectories: research and teaching. Self-funded research groupings drive our research, each aligned with the Centre's strategic objectives. Our teaching activities are centred around the taught BSc (Hons) programme and our MSc (Eng) and PhD programmes. CME is located in the Menzies building on the 2nd floor of the upper campus, providing laboratory services, postgraduate workstations, offices and a lecture theatre.

CME comprises a diverse team of academic staff from the Department of Mechanical Engineering, the Honours Programme Convenor, and support staff, including those in soft-funded positions and PhD candidates who serve as Laboratory Engineers.

We maintain a student-centric approach to research, with teaching and postgraduate supervision at the Honours, Master's, and PhD levels forming the core of our activities. We measure our success by our research outputs, including publications and graduations, and our contributions to local industry through innovative solutions and knowledge transfer.

We foster a collaborative environment where resources, funding, and expertise are shared among the research groupings, promoting interdisciplinary research and enhancing the overall impact of our work. Support staff, funded through a combination of soft-funded positions and project contributions, play a crucial role in ensuring the smooth operation of the Centre. Our well-established laboratories provide the necessary infrastructure to support high-impact research, and we frequently collaborate internally on collective grants, particularly for new equipment or facility upgrades. Moreover, CME is committed to inclusivity, creating a supportive environment where co-supervision of postgraduate projects and shared learning opportunities are encouraged. We take pride in celebrating our achievements, whether successful PhD proposals, research publications, graduations, or grant awards, fostering a strong sense of community within the Centre.

The BSc (Hons) in Materials Science program is coordinated by the Programme Convenor and supported by academic staff in collaboration with the Department of Mechanical Engineering. Moreover, we support postgraduate research from other groups and centres within the department and faculty through access to facilities and expertise.

As a dynamic research centre, we offer extensive expertise in Materials Science and Engineering-related topics and strive to maintain our position as one of the national leaders in the field. Our collaborative environment and facilities enable us to explore complex material relationships, produce internationally recognised research outputs, and support academic and industrial innovation, which aligns with our strategic goals.

2 Nature of Research Activities

Our research activities are defined by a commitment to advancing Materials Science and Engineering in South Africa. Our work spans various materials, focusing on exploring the relationships between process, structure, property, and performance. This approach enables us to address fundamental and applied research challenges, emphasising support for South Africa's manufacturing industry.

Materials in Manufacturing

A key aspect of our research is directed towards developing a competitive and sustainable manufacturing industry in South Africa. We recognise that the growth of such an industry is contingent upon developing and nurturing expertise in Materials Engineering. To this end, our research activities are integrated into a multidisciplinary framework that seeks to strengthen manufacturing technologies. This integration allows us to develop the necessary human resources to support a burgeoning manufacturing economy in South Africa.

Materials Performance in Service

Our research activities also aim to develop expert knowledge of how materials perform during service, assessing their remnant life and implementing remedial actions when necessary. Our work focus includes high-temperature strength and creep performance, fatigue and fracture behaviour, and corrosion and chemical degradation of materials. These efforts are particularly relevant to the chemical, energy, mining, construction, and marine industries in South Africa.

Sustainability

We are committed to developing materials and processes that enhance performance and contribute to a sustainable future. Our research integrates sustainable practices by focusing on materials that can be produced, used, and disposed of to minimise environmental impact. By prioritising sustainability, we aim to support South Africa's manufacturing industry in becoming more environmentally responsible, ensuring that the advancements will continue to benefit society and the planet in the long term.

Interdisciplinary Collaboration and High-Impact Outputs

Our research activities are inherently interdisciplinary, involving collaborations with academic institutions, industry partners, and government agencies. These partnerships enable us to tackle complex materials-related challenges and ensure that our research aligns with national priorities. Our commitment to high-impact research is reflected in our focus on producing publishable outputs in leading international journals and conferences, thereby contributing to the global body of knowledge in the field.

Infrastructure and Capacity Building

CME research infrastructure provides the facilities and equipment necessary to support experimental work. This includes advanced mechanical testing laboratories, microstructure characterisation facilities, and specialised processing equipment. Our research projects are closely tied to postgraduate education, actively involving students in research that advances their technical skills. We also emphasise inclusivity, attracting and developing postgraduate students and postdoctoral fellows from diverse backgrounds, ensuring that our research community reflects the rich diversity of South African and African society.

3 Research groups

CME is structured around specialised research groups, each dedicated to advancing knowledge and innovation within specific areas aligned with our strategic goals. These groups have been established to concentrate their expertise and resources on critical research challenges. By maintaining a focused research agenda, each group contributes to the broader goals of the Centre. These groups, their focus areas, and active projects are summarised alphabetically below. Listed projects might be singular PhD studies or span across several MSc projects.

3.1 Additive Manufacturing (CPAM)

Under the South African Collaborative Programme in Additive Manufacturing (CPAM), the research group focuses on advancing the commercialisation of Additive Manufacturing processes. The overarching aim is to establish a robust and reliable AM process that consistently produces high-quality, load-bearing, and capable fabricated parts. This initiative aligns with South Africa's Additive Manufacturing (AM) Strategy, which aims to position South Africa as a key player in the global AM market. The strategy focuses on establishing the properties of materials produced using AM as well as developing new materials, enhancing process capabilities, and ensuring product quality.

One of the significant challenges in the widespread adoption of AM is the variability in the mechanical properties of produced parts. Several factors, including the characteristics of the alloy, the feedstock powder, the specific AM process parameters, and the subsequent post-processing treatments, influence this variability. The group aims to address these challenges through a multi-faceted approach that includes characterising and qualifying titanium-based alloys, Nickel-based superalloys, precipitation hardenable Aluminium alloys and shape memory alloys, as well as developing new beta-titanium alloys, and refining post-processing techniques such as heat treatments and surface finishing techniques.

The group's work is highly collaborative, involving partnerships with various academic institutions and industry stakeholders, both locally and internationally. For instance, the collaboration with KU Leuven leverages their expertise in microstructural development. The partnership with ETH Zurich focuses on advancing AM technologies using multi-materials, and the collaboration with Nanyang Technological University focuses on fatigue and fracture of AM alloys.

3.1.1 Team

- A/Prof Thorsten Becker (Principal Investigator)
  Focus area: Structural Integrity, Fatigue and fracture, Additive Manufacturing, Digital Image and Volume Correlation, Computational Mechanics
- Dr Nasheeta Hanief
  Research area: Scanning and Transmission Electron Microscopy
- A/Prof Debby Blaine (Stellenbosch University)
  Focus area: Powder Metallurgy, Physical Metallurgy
- Prof Natasha Sacks (Stellenbosch University)
  Focus area: Advanced Manufacturing, Metal Matrix Composites, Tribology, Additive Manufacturing
- Dr Melody Neaves (Stellenbosch University)

Focus area: Additive Manufacturing, Creep, High-temperature testing, Digital Image Correlation
- Mr Maxwell Vos
  Speciality area: Gleeble Engineer

3.1.2 Projects

- **Development of titanium alloys for Additive Manufacturing**

  The project focuses on enhancing the Laser Powder Bed Fusion (LPBF) - an AM process - of titanium alloys to optimise its application in producing high-quality, load-bearing components with minimal post-processing. Traditionally, Ti-6Al-4V, the most widely used titanium alloy in LPBF, presents challenges due to its martensitic α’ microstructure, which is highly brittle. While heat treatment can transform this structure to improve mechanical properties, alternative titanium alloys may offer superior performance without requiring extensive post-processing. The research aims to explore and qualify alpha-beta, near-beat and metastable beta titanium alloys. The project investigates pre-alloyed titanium powders to identify and develop alloys suitable for AM.

- **Tailoring Microstructure and Properties of LPBF-Produced Titanium Alloys**

  During AM, one area of concern is the rapid cooling rates resulting in anisotropic microstructures and residual stresses, which often compromise ductility while enhancing material strength. In the case of titanium alloys, the microstructural characteristics resulting from the AM process include epitaxial columnar grains and needle-like structures, which can vary based on the process parameters. This project investigates the complex relationships between AM process parameters, microstructural features, phase compositions, and mechanical properties in titanium alloys. By manipulating these parameters and potentially utilising in-situ alloying, the study aims to customise the material properties, such as yield strength, tensile strength, and fracture toughness, to exceed those of conventionally manufactured alloys. The objectives include establishing correlations between process parameters and microstructural features, using numerical methods to predict phase compositions, and exploring the mechanical properties of these customised alloys to develop tailored strategies for producing titanium alloys with superior mechanical performance using AM.

- **Exploring the impact of Additive Manufacturing on the microstructural and mechanical properties of Ti-6Al-4V**

  This research investigates the relationships between the microstructure and mechanical properties of Ti6Al4V alloy produced using three different AM techniques: LPBF, Direct Energy Deposition (DED), and Wire Arc Additive Manufacturing (WAAM). Ti6Al4V is a titanium alloy widely used in aerospace, marine, and biomedical industries due to its high strength, corrosion resistance, biocompatibility, and fracture toughness. The study aims to explore how these manufacturing techniques impact the alloy's performance, focusing on fatigue and fracture behaviour.

- **Feasibility of Additively Manufactured, patient-specific metallic articulating implant components**

  The research aims to develop a theoretical model to simulate wear behaviour and assess the feasibility of AM-produced implants based on tribological performance. The expected contributions include providing a framework for evaluating the feasibility of candidate materials for specific joint implants, characterising the wear properties of AM alloys, and offering insights into the potential of AM for producing durable, patient-specific implants.

- **Fabrication of biocompatible Ti-4.7Mo-4.5Fe alloy for orthopaedic applications using Additive Manufacturing**

  Ti-6Al-4V is commonly used in biomedical applications due to its strength, corrosion resistance, and biocompatibility. However, concerns about the long-term health effects of vanadium and aluminium and the mismatch in Young's modulus between the alloy and bone tissue have led to research into developing alternative, low-cost β-type titanium alloys with similar or improved mechanical properties. This research aims to produce Ti-4.7Mo-4.5Fe alloy using LPBF through in-situ alloying, a technique that has not been previously explored for this alloy.

- **Fracture during Laser Powder Bed Fusion processing**

  The project aims to develop criteria for predicting fracture during LPBF; fracture during LPBF typically occurs several layers below the top layer being consolidated, suggesting that thermal stresses from subsequent layers contribute to fracture in previously consolidated layers. The motivation for this research stems from common manufacturing challenges in LPBF, such as distortion and failure, which can lead to dimensional inaccuracies, broken support structures, and poor mechanical properties. Traditional methods to mitigate these issues, such as adjusting component orientation or geometry, require trial and error, making a predictive approach highly desirable. By developing a fracture criterion, this project seeks to more accurately predict fracture occurrences during LPBF, thereby enhancing the reliability and efficiency of the process.

- **Mechanical, fatigue and fatigue properties of AM-produced precipitation-hardenable aluminium alloys**

  This project examines the mechanical properties, fracture toughness, and fatigue properties of precipitation-hardenable aluminium alloys, specifically the AlSi10Mg alloy produced via LPBF. Challenges such as residual stresses, porosity, and anisotropic properties may impact the performance of LPBF-produced parts. The study focuses on understanding how different build orientations and heat treatments (including standard T6 heat treatments and custom-developed heat treatment solutions) influence the material properties.

- **High-temperature mechanical and fracture behaviour of AM-produced nickel superalloys for aerospace applications**

  The project investigates the high-temperature mechanical properties of AM-produced Inconel 718 (In718), a nickel-based superalloy widely used in aerospace applications.

In718 is known for its exceptional mechanical strength at elevated temperatures, making it ideal for high-stress environments. However, the unique microstructure resulting from the AM process poses challenges in understanding and optimising its performance, especially under high-temperature conditions. This research compares the tensile and fracture toughness properties of LPBF-produced In718 with those of its wrought counterparts, particularly above 650 °C, where strength typically diminishes.

- **Mechanical, fatigue and fatigue properties of AM-produced CoCrMo for biomedical applications**

  This project focuses on AM-produced CoCrMo, a commonly used alloy in the biomedical sector for dental and orthopaedic implants due to its excellent corrosion resistance, hardness, and biocompatibility. AM has the potential to overcome the limitations of traditional casting methods, such as porosity and shrinkage; however, the fatigue properties of AM-produced CoCrMo are of concern. The project aims to investigate the mechanical, fracture and fatigue properties of CoCrMo manufactured using LPBF to ensure its reliability for biomedical implants. Key research questions address how the LPBF process influences the tensile and fatigue properties of CoCrMo, the impact of distinctive microstructural features on fatigue performance, and the role of post-processing techniques in enhancing these properties.

- **Producing ternary NiTiX alloys using Additive Manufacturing for biomedical applications**

  This study focuses on developing ternary Nickel-Titanium (NiTiX) alloys with enhanced shape memory properties using Laser Powder Bed Fusion (LPBF) for biomedical applications. NiTi, known as Nitinol, is well-known for its shape memory and superelastic properties, making it a prime candidate for medical implants. However, its high nickel content and conventional manufacturing difficulty present challenges. By using AM, complex geometries can be produced with near-net shape and high density, addressing some of these limitations. The research aims to identify ternary alloy compositions with improved functional properties, biocompatibility, and mechanical performance. The project will explore alloying methods and powder fabrication techniques to produce fully dense parts with optimal shape memory recovery, superelasticity, and biocompatibility. The study will also investigate post-processing heat treatments to enhance further the mechanical performance, cyclic durability, and transformation temperatures of the LPBF-produced NiTiX parts, targeting the production of patient-specific biomedical implants with superior properties.

- **Life prediction of Additively Manufactured alloys**

  The project is focused on assessing the fatigue life of components manufactured through AM using fracture mechanics principles. Fatigue characterisation is essential for components used in applications that involve cyclic loading, such as in aerospace, automotive, and biomedical industries. However, certifying the fatigue life of AM parts presents challenges due to various factors, including AM print parameters, build orientation, surface roughness, inherent defects, residual stresses, and the material's microstructure. The research is centred on adapting the NASGRO fatigue predictive model to account for the unique characteristics of AM-produced alloys. This model takes into consideration the effects of microstructure and residual stresses, builds orientation on fatigue crack growth rates, and establishes specific parameters for the alloy. A fracture mechanics-based model is also being developed to estimate fatigue life, considering non-uniform defect populations identified through X-ray tomography and surface profilometry. The study emphasises the sensitivity of fatigue strength estimates to crack growth thresholds and stresses the importance of considering multiple crack initiations.

3.1.3 Collaborators

- Dr Arno Jansen van Vuuren (Centre for High-Resolution Transmission Electron Microscopy, Nelson Mandela University)
- Dr Lerato Tshabalala (Council for Scientific and Industrial Research)
- Prof Deon de Beer (Centre for Rapid Prototyping and Manufacturing, Central University of Technology)
- Dr Andrew Venter (South African Nuclear Energy Corporation)
- Prof Ramamurty Upadrasta (Nanyang Technological University, Singapore)
- Prof Kim Vanmeensel (Katholieke Universiteit Leuven, Belgium)
- Prof Louise Jennings (University of Leeds, United Kingdom)
- Prof Markus Bambach (ETH Zürich)

3.1.4 Funding/Partners

- Department of Science and Innovation
- National Research Foundation
- Council for Scientific and Industrial Research
- HH Industries (Pty) Ltd
- Craniotech (Pty) Ltd
- EOS GmbH (Germany)

3.2 Aluminium (Aluminium Research Group, ARG)

CME has had a long-standing research relationship with various aluminium industry role players, with Hulamin Rolled Product being the most prominent. Through this collaborative relationship, a focus on aluminium metallurgy has been established, and the context of aluminium metallurgy has become a golden thread through the post-graduate knowledge-building pathway in the CME, most notably through the presentation of the Wrought Aluminium Course. The increased research focus on aluminium has been the catalyst for the growth of Aluminium research, where CME has established itself as the leading research team in South Africa in the field of wrought aluminium products and processes. The group is also endorsed by the Aluminium Federation of South Africa (AFSA) and was represented on the steering committee to finalise the South African Aluminium Industry Masterplan document for the DSI.

The ARG strives to make a difference in South Africa's aluminium industry. Its research focus is driven by industrial and applied research and centres around various facets of aluminium processing and its value chain. The areas of expertise encompass a range of critical research areas, such as experimental physical metallurgy, computational and modelling techniques, and machine learning and data science applications. The research that the ARG is currently working on is being fed back into the industry and is starting to have a meaningful impact on the collaborating industry partners.

The group is currently working on a Department of Trade and Industry THRIP-funded project in collaboration with Hulamin Rolled product. The research focuses on the semi-fabrication stage of aluminium alloys used in packaging and beverage cans. As such, a large number of postgraduate research projects focus on aspects of the thermomechanical processing of beverage can alloys.

3.2.1 Team

- Dr Sarah George (Principal Investigator)
  Focus area: Physical metallurgy and thermomechanical processing
- Dr Gerard Leteba
  Speciality area: Advanced transmission electron microscopy characterisation techniques
- Mr Ernesto Ismail
  Focus area: Design, Computation/Modelling, Machine learning
- Mr James Dicks
  Focus area: Polymer coating of aluminium packaging material
- Mr James Hepworth
  Focus area: Instrumentation and sensors
- Mr Maxwell Vos
  Speciality area: Gleeble Engineer

3.2.2 Research projects

- **AA5182 anisotropy**

  The physical properties of AA5182-H48 coated beverage can end stock (CES) sheet show variation in tensile properties and plastic strain ratio relative to the rolling direction, known as anisotropy. This anisotropy is influenced by the crystallographic texture of the rolled sheet, resulting in differences in the panel diameter of the drawn can end. In AA5182-H48 CES, this anisotropy is consistent and managed using a non-round blank during end-making. Understanding the mechanism behind the yield strength anisotropy of strain hardened and recovered AA5182-H48 sheet can help improve control over this parameter, leading to more consistent properties of the formed can end. This could enable light-weighting of the can end through gauge reduction of the CES sheet. This study investigates the mechanisms related to anisotropy in supplied coated sheets and in material exposed to practice conditions.

- **AA8XXX battery foil alloy investigation into intermetallic particle and dispersoid evolution during homogenisation**

  In commercial AA8021 and AA8079 foil, alloying elements such as iron (Fe) and silicon (Si) are present either in solid solution or as particles within the aluminium matrix. The microchemistry of the alloy affects key material properties, including formability, electrical conductivity, and strength, which are essential for foil products used in EV batteries. The structural characterisation of these intermetallic particles (IMPs) and the mapping of their evolution during homogenisation—focusing on phase identification, structure, and composition—are poorly understood. This understanding is crucial, as the initial structure of the IMPs underpins the evolving microstructure during homogenisation, as well as the development of microstructure and properties in downstream processes such as hot and cold rolling. This study employs two- and three-dimensional approaches to characterise and quantify the IMPs and dispersoids in the material. The three-dimensional technique has been developed to extract the particles without losses, enabling advanced characterisation using transmission electron microscopy (TEM) and scanning transmission electron microscopy (STEM) to investigate the local structure and elemental distribution within individual particles. The high-level characterisation data will inform alloy composition, homogenisation, and processing parameters to achieve the desired mechanical properties.

- **Development of Paramaterial software**

  Experiments that test for the mechanical properties of materials typically generate large amounts of raw data, which must be cleaned and processed before meaningful analysis can be performed. Manual processing of this data is often time-consuming and susceptible to errors. Furthermore, the necessary processing steps are usually similar for various datasets, given that mechanical testing procedures are standardised. This project addressed these issues by developing a software toolkit for automated processing and repeatable analysis of mechanical test data. The toolkit was developed as a pip installable Python package, Paramaterial, and designed for Jupyter Notebooks. The usage of Jupyter Notebooks makes explicit the steps a user takes in processing and analysing the data, thus providing traceability and repeatability. The functionalities of Paramaterial were demonstrated by processing and analysing several datasets sourced from the literature and CME. The example datasets used in the demonstrations consist of 100 uniaxial tensile tests and 56 plane-strain tension tests on aluminium AA6061, 70 uniaxial compression tests and 40 plane-strain compression tests on aluminium AA3104. The Jupyter Notebooks containing the code for these demonstrations serve as tutorials for future toolkit users. Code documentation and user manuals are provided, making the software readily available to improve the quality and quantity of processed experimental data in the field.

- **AA5182 anisotropy – a machine learning approach**

  Rolled AA5182 sheet is used to manufacture the ends of aluminium beverage cans. The material exhibits anisotropy, with varying strengths in different directions relative to the rolling direction. The research focuses on implementing machine learning techniques to predict the proof strength both in the longitudinal direction and at 45° relative to the rolling direction, as well as the anisotropic variation denoted as “L-45°”. Additionally, a classification approach is employed, with the models designed to predictively classify lots as having either high or low levels of anisotropy. The subsequent phase examines the influence of process parameters on inter-lot anisotropic variation. In-depth analysis reveals significant relationships between specific manufacturing variables—such as the exit temperature in the cold roughing mill, coating line temperature, cold work strain, and homogenisation soak time—and the observed anisotropy. These models then identify interdependencies between these variables, providing insights into how anisotropic variation can be effectively controlled. Based on the insights derived from the predictive models, recommendations are proposed to minimise inter-lot anisotropic variation in the final product. These suggestions include reducing the exit temperature of the cold roughing mill, raising the temperature in the coating line, carefully controlling the cold work strain, and lengthening the homogenisation soak time.

- **Investigation into the effect of interpass time on the texture development during hot rolling of AA3104**

  This work aims to study the impact of minor changes in the hot-rolling industrial process on the final properties of the material; when a strip of can body stock material with a specific plate number is rolled on a single stand reversing mill, the leading end, centre, and tail of the strip will experience different inter-pass times on the hot finishing mill. This can lead to variations in recrystallisation, deformation, and texture development. The differences in inter-pass times may result in varying strain accumulation, ultimately leading to microstructure, properties, and texture variability within the material. If texture is not appropriately controlled, uneven rims may develop on the cans during thermoforming, resulting in material loss and reduced productivity. This project simulates hot finish rolling, considering the variability in interpass time based on industrial mill data. Other process parameters, such as strain per pass, strain rate, and temperature, will remain constant. The samples will undergo recrystallisation, and both the recrystallised and hot-deformed samples will be analysed. This project aims to characterise microstructure and texture evolution for both leading and tail-end samples to understand their development better.

- **The development of a formability rig for the generation of forming limit diagrams of automotive aluminium alloys**

  Testing the formability of a material is crucial for verifying its mechanical properties when manufacturing car door inners and outers using forming processes. The formability of the final sheet is influenced by factors such as composition, process history, etc. Typically, two standards are used to evaluate the formability of a material: the ASTM standard and the EN/BS standard. This project involves designing and installing a suitable forming press based on the EN/BS Nakajima standard. The setup includes the use of DIC to measure strain during forming tests. Once the equipment is operational, the project will assess the formability of various sheets, focusing on those used in electric vehicle structures. The experimental component will investigate the effect of processing parameters on the formability of the sheet. This will be achieved by generating forming limit diagrams for each material.

- **Investigating the lab simulation of the complete homogenisation and hot rolling process on AA3104**

  This project looks at variations in the homogenisation practice before breakdown rolling and how these variations will result in varied intermetallic particle phase distributions and major variations in the dispersoid sizes and distribution. The industry has identified variability in the earing owing to minor changes in the homogenisation practices, where earing is related to the mechanical properties and preferred crystallographic orientation of grains within the microstructure (the texture). This project is intended to be a proof of concept project to test the viability of a full through-process lab scale simulation of the hot rolling of aluminium alloys, from homogenisation through rough (or breakdown) rolling and finish rolling. This project will use cast DC ingot as a source material. The material will then be exposed to varied homogenisation practices that result in varied IMP and dispersoid sizes and distributions. The homogenised ingot material will then be "hot rough rolled" at Mintek's hot rolling mill. Samples will be extracted for simulated "hot finish rolling" using plane strain compression testing on the Gleeble 3800. The mechanical properties, the microstructure, and the texture are characterised, and a correlation between homogenisation parameters and texture will be investigated.

- **AA3104 sag and creep-resistant microstructures**

  Hulamin has experienced sag in AA3104 can body stock (CBS) transfer bars during transportation from the breakdown to the finishing mill. Excessive sag results in bottom scuffing of the slab on the roller table, leading to surface defects in the final product. It has been observed that increasing the strain rate on the final pass of the breakdown mill results in a slab that is resistant to sag. To better understand the operating mechanisms, the creep response of materials hot-deformed at different Zener–Hollomon parameter (Z) values needs to be evaluated experimentally. During hot deformation, the flow stress behaviour of the material is influenced by strain, strain rate, and temperature. The temperature and strain rate dependence of plastic deformation can be analysed using Z, which incorporates both variables. The constants for the Arrhenius-type equation can be determined experimentally through hot compression testing across a range of temperatures and strain rates. This project aims to determine the constants for the Arrhenius-type Zener–Hollomon equation for the AA3104 aluminium alloy using uniaxial compression testing on the Gleeble 3800. Tests will be conducted on a set strain using various temperatures and strain rates. The constants will be determined, and the microstructures will be evaluated after deformation and post-deformation recrystallisation to investigate the relationship between Z and microstructure.

- **Dispersoid development in AA3104 during homogenisation**

  The production of AA3104 sheet metal for manufacturing beverage can bodies is complex due to the very stringent requirements of the final sheet. Each step of the processing route is critical for developing the microstructure and the mechanical properties of the final sheet. These steps include casting, homogenisation, hot rolling, cold rolling and coating. Homogenisation of AA3104 DC-cast ingot results in several critical microstructural changes. These changes include diffusion of solute elements for an even composition and solute distribution across the structure, intermetallic particle phase transformation from the β–Al_6(Fe, Mn) form to the harder α-Al_x(Fe, Mn)$_3$$Si_2$ form, and the formation of critical dispersoids (typically Mg_2Si) that are the main feature driving, or retarding, recrystallisation during the latter stages of hot rolling. The effect of homogenisation temperature variation on the intermetallic particle phase evolution and the dispersoid growth and distribution is investigated to characterise the impact of time and temperature of homogenisation on the intermetallic phase balance and dispersoid size and distribution. The project uses image analysis, with both light and electron microscopy, as well as matrix dissolution/particle extraction to investigate the inter-metallic particle and dispersoid structures in AA3104 aluminium alloy samples after a range of homogenisation practices, variations in temperature and time-at-temperature for two AA3104 composition variations, a standard alloy and a Si-lean alloy. Using the images and quantitative analysis of particle size and distribution, this work aims to calculate a normalised Zener pinning pressure associated with the structures to hypothesise on the effect of these on the propensity of the material to recrystallise during the hot rolling, cold rolling, and batch anneal steps during the production of flat rolled sheet.

- **Incorporation of realistic geometries of inter-metallic particles in a finite element plasticity model of wrought aluminium**

  The evolution of microstructure in wrought aluminium is essential to the final properties of the material. Controlling this evolution is important to ensure that the load on the rolling mills remains within operational bounds. This project aims to incorporate geometries of intermetallic particles obtained through photogrammetry of SEM images of representative particles extracted from the aluminium matrix in a finite element plasticity model. The project aims to build a workflow from SEM image to mesh generation to simulation of load transfer between embedded particles and the surrounding matrix. This work will be essential in developing representative volume elements (RVEs) capable of simulating various parts of the rolling process and is one of several steps required to make microstructurally accurate finite-element models. The work can further be extended by incorporating realistic fracture and phase-change models in the simulation of the particles. Once this is done, the models can be used to simulate the change in size, shape, and distribution of the particles during rolling. The models would be calibrated against experimental data. Once calibrated, the models can be used to investigate the effects of changing process parameters on the evolution of the particles.

3.2.3 Collaborations

- Dr Arno Jansen van Vuuren (Centre for High-Resolution Transmission Electron Microscopy, Nelson Mandela University)
- Dr Paul Evans (Technology Strategy Consultants, United Kingdom)
- Prof Knut Marthinsen and Prof. Ida Westermann (Norwegian University of Science and Technology, Norway)
- Prof Andrew McBride (University of Glasgow, United Kingdom)
- Prof Jürgen Hirsch (Speira, Germany)
- Prof. Olaf Engler (Speira, Germany)

3.2.4 Funding/Partners

- Hulamin Rolled Product, Pietermaritzburg, South Africa
- Department of Trade, Industry and Competition (dtic)

3.3 Full-field Fracture Mechanics

CME has a history of expertise in the field of fracture mechanics, originally established by Emeritus Professor Robert Tait as one of the leading organisations in this discipline within South Africa. While Fracture Mechanics is a broad field, CME focuses on advancing the measurement of failure and fracture properties in laboratory-based settings, using modern measurement techniques such as digital image correlation (DIC), digital volume correlation (DVC), and

High-angular Resolution electron backscatter diffraction (HR-EBSD) to enhance the accuracy and reliability of these measurements.

The research is centred on advancing the understanding of failure and fracture properties by developing and applying DIC and DVC techniques. These methods provide a unique advantage over traditional approaches, offering detailed failure property information across a wide range of materials, resulting in a more precise understanding of their fracture behaviour. The group aims to comprehensively understand the material property and failure mechanisms by combining full-field displacement or strain data with computational models. This integration allows for considering various factors, such as material heterogeneities, complex loading conditions, and different crack propagation modes. These are crucial for developing predictive models applicable to engineering design and analysis of materials and structures.

3.3.1 Team

- A/Prof Thorsten Becker (Principal Investigator)
  Focus area: Structural Integrity, Fatigue and fracture, Additive Manufacturing, Digital Image and Volume Correlation, Computational Mechanics
- Dr Devan Atkinson
  Focus area: Digital Image and Volume Correlation, Machine Learning
- Dr Abdo Koko (National Physical Laboratory, United Kingdom)
  Focus area: Micromechanics, Strain measurements, Materials Characterisation, Fatigue and Fracture

3.3.2 Projects

- **Adaptive modular Digital Image and Volume Correlation algorithm**

  This project explores the application of artificial neural networks (ANNs) to enhance the accuracy and precision of DIC by enabling dynamic subset selection (DSS). The traditional method of global subset size assignment in DIC is suboptimal, mainly when dealing with spatially varying speckle patterns and complex displacement fields, as it compromises either noise suppression or spatial resolution. This research considers an approach that utilises Artificial Neural Networks (ANNs) to predict random errors based on image information, such as speckle pattern quality and noise characteristics, before the DIC process. By leveraging the flexibility of ANNs, this project develops a modular, open-source DIC framework capable of spatially and temporally independent correlation parameter assignment.

  The successful implementation of ANN-based DSS has the potential to significantly advance state-of-the-art DIC, offering a powerful tool for researchers and engineers working with complex displacement measurements in materials and structural analysis.

- **Extended Digital Image Correlation algorithm for discontinuous displacement and strain data**

  The project seeks to advance the existing open framework DIC algorithm to address the limitations of accurately capturing data in regions with discontinuities, such as cracks and shear bands, leading to poor correlation results in these critical areas. Incorporating advanced error correction methods aims to improve the accuracy of displacement and strain measurements near and across discontinuities. This enhancement is particularly relevant for laboratory investigations of fatigue and fracture, where precise measurements are crucial for extracting failure properties.

Its motivation is driven by the upcoming "Discontinuity DIC Challenge" by the International DIC Society (iDICs), which emphasises the importance of developing DIC algorithms that can handle discontinuities effectively. By extending our existing DIC algorithms, the algorithm will remain relevant and valuable for real-world applications in fatigue and fracture investigations.

- **Enhancing Scanning Electron Microscopy through Stereo μDIC Integration**

  This project focuses on advancing Scanning Electron Microscopy (SEM) capabilities by integrating micro Digital Image Correlation (μDIC) techniques to address critical metrology challenges. In the context of Materials Science and Engineering, precise measurement and analysis of material deformation, particularly at the microscopic level, are essential for developing new materials and improving existing ones. Traditional SEM techniques, while providing high-resolution images, are limited to in-plane analysis and cannot accurately measure out-of-plane components. This limitation hinders the comprehensive understanding of material behaviour under stress, particularly in the development of shear bands (plastic deformation) and the formation of cracks. The main research objective of this project is to enhance SEM capabilities by incorporating a novel stereo μDIC method, enabling three-dimensional analysis of material deformation. This involves using advanced four-quadrant backscattered electron (BSE) detectors to capture topographical changes and improve the accuracy of 3D reconstructions. By developing this methodology, the project aims to provide a more detailed and accurate understanding of crack growth mechanisms and plastic deformation in materials such as Al 5052 alloy.

3.3.3 Collaborators

- A/Prof. Johan Hoefnagels (Eindhoven University of Technology, Netherlands)

3.3.4 Funding/Partners

- University Research Committee, University of Cape Town
- MatchID (Belgium)

3.4 Green Hydrogen

A new focus has been directed toward the green hydrogen economy in developing advanced materials for green hydrogen applications, explicitly targeting the challenges associated with hydrogen embrittlement in conventional materials. The work aims to design, synthesise, and characterise existing and new alloy systems that demonstrate resistance to hydrogen-induced damage. It integrates fundamental materials science with applied engineering, investigating the atomic-scale interactions between hydrogen and alloy systems alongside computational tools such as CALPHAD and advanced experimental techniques, including neutron diffraction and electron microscopy.

The work is motivated by global sustainability goals, particularly the crucial role of green hydrogen in achieving carbon neutrality. The group aims to contribute to practical solutions for the hydrogen economy by advancing the understanding and development of hydrogen embrittlement alloys.

3.4.1 Team

- A/Prof Thorsten Becker (Principal Investigator)
  Focus area: Structural Integrity, Fatigue and fracture, Additive Manufacturing, Digital Image and Volume Correlation, Computational Mechanics

3.4.2 Project

- **Additive Manufacturing of High Entropy Alloy for Potential in Hydrogen Storage Applications**

  The research project focuses on developing an aluminium-doped CrCoNi-based High Entropy Alloy (HEA) tailored for hydrogen storage applications, utilising AM techniques. The project aims to address the issue of hydrogen embrittlement, a significant challenge in hydrogen storage technologies, by leveraging the superior mechanical properties of HEAs, such as high strength, ductility, and fracture toughness. Through a series of carefully planned experiments, including alloy design, fabrication, hydrogen charging, and embrittlement resistance analysis, the project seeks to create a hydrogen-resistant material that can enhance the safety and efficiency of hydrogen storage systems. The use of additive manufacturing allows for the precise control of microstructures, further optimising the material's performance in hydrogen environments.

3.4.3 Collaborators

- Prof Prathieka Naidoo (Stellenbosch University)

3.4.4 Funding/Partners

- University Research Committee, University of Cape Town

3.5 Physical Metallurgy

The Physical Metallurgy Research Group focuses on broadening our understanding of microstructure development in engineering metals and the consequent relationships with mechanical properties. The research explores microstructure development during processing and heat treatment and focuses on the close association between microstructure constitution, morphology and stability. A broad range of analytical microscopy techniques are deployed to characterise the microstructures, which in some cases includes resolution at near atomic levels.

3.5.1 Team

- Prof Robert Knutsen (Principal Investigator)
  Research area: Mechanical property measurement, processing and microscopy
- Dr Nasheeta Hanief
  Research area: Microscopy and analysis
- Ms Soraya von Willingh

Speciality area: Mechanical property measurement, processing and microscopy

3.5.2 Research projects

- **Influence of initial process excursions on microstructure and property evolution in X20 steel during artificial ageing**

  Incomplete cooling through the martensite start and finish temperature range before tempering is being considered as a possible process excursion relative to conventional normalisation and tempering practices for X20 steel. The X20 steel is used for the main steam pipe on a coal-fired power plant where standard service operating conditions are within the range of 520-540 °C and internal pipe pressures up to 18 MPa. Although the microstructure, and hence strength properties, are expected to evolve during lengthy service exposure (> 100 000 hours), the expectation is that any deviations in conventional normalisation and tempering processing could influence the microstructure and strength property evolution. Standard and excursion heat treatments are performed, followed by artificial laboratory ageing to accelerate microstructural change. Stress relaxation and notched-bar constant displacement rate tensile tests are performed to assess the evolution of strength and fracture properties. The microstructure evolution is characterised using a combination of light and electron microscopy techniques.

- **Synergistic work hardening and precipitation hardening in AA3104 aluminium alloy**

  Work hardening and recovery are generally reversible during metal processing and act in opposite directions to harden or soften the metal. When precipitation hardening occurs during recovery periods, the subsequent work hardening is enhanced by the obstacles to dislocation movement provided by the coherent (or semi-coherent) precipitates. In the case of continuous or extensive plastic deformation, the movement of dislocations through these precipitates will lead to dissolution with a concomitant reduction in work hardening. However, different behaviours were detected during the cyclic deformation and recovery of the AA3104 aluminium alloy. The enhanced contribution of precipitation hardening is maintained through the deformation event, and the work hardening trend is maintained above the level expected if the precipitates are destroyed by dislocation movement. Consequently, we argue that the nature of the precipitates that occur during the recovery period is most likely incoherent and, hence, stable during deformation. The evolution of microstructures during recovery and deformation is being studied using analytical transmission electron microscopy to test this hypothesis.

- **Dislocation density measurement in austenitic stainless steel using X-ray diffraction and electron microscopy**

  X-ray diffraction is an indirect method that can be used to measure dislocation density in crystalline materials and has potential as a non-destructive evaluation tool. A test case is being considered using a standard austenitic stainless steel to evaluate the method's sensitivity in measuring dislocation levels in samples that have been fatigued to different levels. The X-ray data is being compared to other direct methods using transmission electron microscopy and electron channelling contrast imaging and to the indirect electron backscattered diffraction orientation imaging technique.

- **Grain structure analysis of additive manufactured Ti-6Al-4V alloy as a function of build energy**

  In most instances, the grain structure developed in the Ti-6Al-4V alloy during selective laser melting is extended in the build direction at lengths much greater than the individual powder layer thickness. The common thinking is that the alloy has a strong tendency towards epitaxial growth. However, there is a limit to the length of the grains, and under certain build conditions, the structure is equal. The hypothesis is that some degree of grain rotation occurs during the successive melting and solidification events as the build progresses layer by layer. Hence, conditions may develop towards unfavourable growth, and re-nucleation may occur. Although this behaviour is challenging to detect due to the martensitic transformation, attempts to unravel the growth pattern are being investigated using high-resolution electron orientation imaging in the scanning electron microscope.

- **Effect of base metal oxygen content and oxygen activity on the mechanical properties of grey cast iron**

  The oxygen level in the liquid metal is critical for inoculation during solidification since it influences the graphite structure that forms. The graphite structure, in turn, strongly influences mechanical properties. Hence, controlling oxygen levels and activity is important for maintaining the optimum performance of the cast product. Several factors are being investigated, such as the effect of holding time on oxygen levels and the consequent effect on graphite nucleation, graphite morphology and mechanical properties of grey cast iron.

3.5.3 Collaborations

- Mr Mike Shirran (Independent)
- Ms Londiwe Motibane (Council for Scientific and Industrial Research)
- Dr Johan Westraadt (Ohio State University, United States of America)
- Dr Paul Evans (Technology Strategy Consultants, United Kingdom)

3.5.4 Funding/Partners

- Eskom
- Atlantis Foundries
- Technology Strategy Consultants (United Kingdom)

3.6 Sustainable Composites

The Sustainable Composites group focuses on characterising sustainable materials under extreme loading conditions and investigating blast wave propagation in urban environments. The research aims to develop and optimise materials that can withstand high strain and impact forces, including blast loads while serving as sustainable alternatives to conventional petroleum-based materials. Emphasising both sustainability and practical implementation within South Africa, the group's work contributes to creating safer, more environmentally conscious engineering solutions that are also cost-effective and feasible for local industries. Additionally, the group explores the complex dynamics of blast waves in urban settings, conducting small-scale tests with modelled buildings to understand the impact of explosive loads better and enhance safety measures. By integrating these research areas, the group aspires to develop resilient structures capable of enduring extreme conditions while minimising their environmental footprint.

3.6.1 Team

- Dr Sherlyn Gabriel (Principal Investigator)
  Focus area: Composites manufacturing, composite constituent materials, blast and impact loading, urban blast environments,
- Mr James Dicks
  Focus area: Polymer matrices, polymer synthesis

3.6.2 Projects

- **Material behaviour of resins typically used as composite matrices: Comparison between petroleum and bio-based formulated products.**

  This project aims to understand various material properties, including compression, tensile, flexural, and impact, of resins so that relations can be made to the structural integrity of a composite that uses the material as a matrix.

- **Analysis of interlaminar properties on GFRP laminates under different weave orientations**

  Glass fibre-reinforced polymer (GFRP) composites are widely used in various structural applications due to their high strength-to-weight ratio, corrosion resistance, and design flexibility. Interlaminar toughness is an important parameter, especially considering that a dominating mode of failure is delamination in impact loading conditions, as it governs the resistance to delamination and crack propagation between adjacent layers. Understanding how to weave orientation and stacking sequence influence interlaminar properties can lead to the development of optimised composites.

- **Sustainable composites and plastics in South Africa: Available materials, suitable manufacturing methods, end-of-life aspects**

  Plastics and composites have become integral to our daily lives due to their versatility and convenience. However, the alarming environmental impact of plastic waste has led to a growing emphasis on recycling to mitigate this issue. While recycling is often hailed as a sustainable solution, it is crucial to evaluate the process and its limitations critically. This extends to other end-of-life options available for these products. This study explores the challenges and opportunities associated with composites and plastics, shedding light on their effectiveness, environmental implications, and potential for improvement within South Africa.

- **Sustainable viability of replacing a part or material used in a commercial plane with either a plant-based or eco-friendly option**

  Composites are extensively used in aerospace applications. While most sustainability efforts in that industry are focused on fuel and reduced mass aspects of a plane, this project focuses on whether the materials used can be replaced by eco-friendly alternatives. Alongside investigating material properties, economic and social aspects of this change are considered.

- **Blast and impact behaviour of sustainable composites**

  This research explores the response and failure of composites containing sustainable materials (like medium-density fibreboard (MDF), bio-based resins and natural fibres) subjected to air-blast and high-impact loading. The goal is to determine the viability of sustainable/semi-sustainable composites in extreme loading conditions.

- **The Effect of scaling building configuration blast experiments**

  Explosions in an urban setting have a significant negative impact. The loading effects caused by the blast's interaction with structures need to be further understood. In conjunction with this, the effects of scaling and understanding the limitations of laboratory experiments are equally important, given the cost incurred for full-scale experiments.

- **Urban blast environments: comprehensive look into explosive parameters influence structural response, human injury and city layouts**

  This research explores the harmful effects of explosions on urban environments, where civilians are affected predominately. This work aims to address global issues with a blast to inform policymakers, engineering, and public health approaches. Much of this research is in collaboration with members of the International Blast Injury Research Network (https://www.blastinjurynetwork.com/)

3.6.3 Collaborations

- Dr Yonatan Sahle (Department of Archaeology)
- Dr Jack Denny (University of Southampton, United Kingdom)
- Prof Genevieve Langdon (University of Sheffield, United Kingdom))
- Dr Andrew Barr (University of Sheffield, United Kingdom))
- Dr Mohammed Ahmed (University of Somalia)

3.6.4 Funding/Partners

- International Blast Injury Research Network (IBRN)
- UCT/TuoS Scholar Programme (University of Sheffield)
- National Research Foundation
- Royal Society Grant for International Science Partnerships Fund
- University Research Committee, University of Cape Town

3.7 Sustainable & speciality polymers

The Sustainable & Specialty Polymer Group evolved from research on biobased polymers and composites that began under Chris Woolard in 2017. Officially established in 2022 and now led by James Dicks, the group aims to address a future-centred approach to polymers through the development of sustainable polymers and polymers for advanced engineering applications. Research areas within the group include the valorisation of agri-resources from industrial crops and agricultural waste streams for the efficient synthesis of monomers aligned to the principles of "green chemistry", the synthesis of monomers for polymers with specialised properties such as covalent adaptable networks, chemically recyclable polymers, self-healing polymers, and shape memory polymers, the application of novel monomers for additive manufacturing technologies to produce innovative 3D printed polymers, and the optimisation of additive manufacturing technologies to enhance the performance of the 3D printed polymers.

3.7.1 Team

- Mr James Dicks (Principal Investigator)
  Focus area: monomer and polymer chemistry, materials characterisation, mechanical properties, additive manufacturing
- A/Prof Wei Hua Ho
  Focus area: Computational fluid dynamics, ocular fluid dynamics, biofluids

3.7.2 Projects

- **Development of Sustainable Monomers and Natural Fibres for Composite Materials**

  Fibre-reinforced polymer matrix composites constitute an important class of materials for engineering applications. However, it is typical for petroleum-derived thermosetting polymers and glass fibres to be commonly used, making them unsustainable materials. This project focuses on addressing these issues through the development of sustainable alternatives. One focus area is the development of biobased thermosetting polymers through the functionalisation of agricultural feedstocks. Another focus area is placed on using natural fibres and investigating surface treatment modifications for enhancing the mechanical properties of the composite material. The research aims to leverage agri-resources for efficient synthetic modifications to produce materials that are both sustainable and offer excellent mechanical properties.

- **Synthesis and Characterisation of Biobased Semi-Rigid Polymeric Foams**

  Semi-rigid polymeric foams are traditionally fabricated using petroleum-derived thermosetting polymers and blowing agents that can be detrimental to the environment. Being thermosetting polymers, they can neither be recycled nor naturally degrade, leading to waste accumulation. This research focuses on developing biobased monomers that are suitable for fabricating biodegradable semi-rigid polymeric foams using environmentally benign blowing agents. The project also focuses on the ability to control and engineer the mechanical properties of the polymeric foams, ascertaining fundamental micromechanical relationships between structure, properties, and performance. This research aims to address the need for sustainable engineering polymeric foam materials.

- **Biobased Polymers for Vat Photopolymerisation Additive Manufacturing**

  The majority of biobased polymers suitable for vat photopolymerisation additive manufacturing rely on functionalisation using petroleum-derived reagents, thus diminishing their overall sustainability. This research focuses on using biobased and environmentally benign molecules to achieve suitable functionalisation for photopolymerisation. A focus on the use of itaconic acid is explored to achieve a variety of monomers such as unsaturated polyesters, unsaturated polyester amides, β-hydroxyesters, diester reactive diluents, and multifunctional monoester monomers. The research aims to address the need for (meth)acrylate-free monomers and to achieve wholly biobased compounds that also possess excellent properties.

- **Biobased Covalent Adaptable Network Polymers**

  This project involves the synthesis of monomers for covalent adaptable network polymers that can be additively manufactured. This project aims to sustainably create polymers with advanced properties such as self-healing, chemical recyclability, and shape memory, which have potential applications in biomedical engineering, soft robotics, and actuators. Particular focus is placed on using thiol-X chemistry and dynamic β-hydroxyesters to achieve these polymers.

- **Incorporation of Microalgae into Additively Manufactured Polymers**

  Microalgae presents a potential opportunity as a sustainable feedstock for several biobased platform molecules that can be incorporated into monomers. Furthermore, microalgae cells also have the potential to be encapsulated into materials for biomedical therapeutics. This research aims to identify and integrate platform molecules from microalgae into monomers for additively manufactured polymers and the encapsulation of microalgae cells within additively manufactured hydrogel polymer networks for biomedical therapeutics.

- **Biobased Ionomeric Polymers**

  Ionomeric polymers contain ionic species within the polymer structure, leading to strong intermolecular interactions. This research explores the use of biobased feedstocks for the synthesis of ionomeric polymers and imparts ionomeric and hydrogen bonding intermolecular interactions to achieve self-healing polymers under thermal stimulus. It also investigates potential synthesis strategies to impart these properties within biobased polymers using sustainable synthesis strategies.

- **Polymeric Materials for Additively Manufactured Biomedical Flow Phantoms**

  This project aims to develop polymeric materials suitable for additive manufacturing of biomedical flow phantoms used in particle image velocimetry fluid dynamics measurements. The research focuses on creating polymers that can be used in vitro to study fluid dynamics in biomedical conditions such as aneurysms by satisfying the need for geometrically accurate additive manufacturing of flow phantoms that emulate the mechanical properties of biological tissue, have a low refractive index, and are optically transparent.

- **Biobased Polymers for Vacuum Investment Casting**

  Vacuum investment casting is an efficient fabrication technology for highly detailed low- to medium-volume production of metallic objects. In recent years, the development of vat photopolymerisation additive manufacturing of the master article has presented an effective fabrication technology. However, the monomers used are almost exclusively petroleum-derived and thus present environmental concerns. This research involves synthesising and developing biobased resins that satisfy both the requirements for vat photopolymerisation additive manufacturing and act as efficient “burnout polymers” for vacuum investment casting. The research addresses the need for environmentally benign monomers that can be employed in AM to produce excellent investment casted metallic objects.

- **Parametric Optimisation of Masked Stereolithography Additive Manufacturing**

  Masked stereolithography additive manufacturing is a layer-by-layer vat photopolymerisation fabrication technology for polymeric materials. The processing parameters employed during fabrication strongly influence the overall mechanical properties achieved in the polymer. This research focuses on optimising the efficacy of masked stereolithography additive manufacturing by understanding the fundamental relationships between the chemistry of monomers and processing parameters during AM fabrication. A statistical approach is used to ascertain a multi-factor and multi-objective parametric optimisation, underpinned in its relationship to the underlying polymer chemistry dictating these relationships to properties. This research aims to enhance the performance and quality of the resulting AM-fabricated polymer products for engineering applications.

3.7.3 Collaborations

- Ms Amy Sephton and Mr Nkosingiphile Mazibuko (Iziko South African Museums)
- Ms Linki Nel (Algaeholix (Pty) Ltd)

3.7.4 Funding/Partners

- University Research Committee, University of Cape Town
- Department of Trade and Industry

BSc(Hons) in Materials Science programme

Our BSc(Hons) Materials Science programme is structured with coursework and a laboratory-based research project, providing candidates with theoretical and practical skills and knowledge in Materials Science and Engineering. The degree program is hosted within the Centre, which gives candidates exposure and participation in research activities and introduces them to several industry associations. We aim to equip our graduates with the knowledge and skills to adequately pursue postgraduate studies and enter relevant workplaces within the Materials Science and Engineering industries. Notably, the BSc(Hons) is a strong feeder for our MSc and PhD programs.

3.8 Programme curriculum and teaching staff

The BSc(Hons) Materials Science degree program comprises eight courses totalling 120 credits, as outlined in Table 1. These courses encompass a range of theoretical, practical, and analytical topics relevant to materials science. The curriculum ensures a coherent and synergistic learning experience, aligning with contemporary knowledge, skills, and values in Materials Science and Engineering.

Table 1: BSc(Hons) Materials Science degree programme

Course code	Course name	Credits	NQF level
MEC4091Z	**Materials Science Honours Research Project** Students are required to attend a series of lectures and practicals on experimental techniques. Each student will be given an individual laboratory project on a problem relating to materials. A period of twelve weeks is allocated for the project and on completion a treatise must be submitted for examination.	**36**	**8**
MEC4100Z	**Polymeric Materials** This course aims to develop an understanding of the structure, processing, and properties of polymeric materials. Topics include: polymer nomenclature; morphology; bonding; molecular weight, polymerization, crystallisation; polymer types; rheology; applications; polymer identification; polymer modification, additives; analytical techniques; biodegradability; and selection and design. Throughout the course the relationships of structure-properties-processing are described.	**12**	**8**
MEC4133Z	**Engineering Performance of Materials** This course provides an understanding of the relationship between the design, environmental conditions and material properties on the reliable and safe operation of engineering structures. This understanding is presented through the link between the process, structure, and material properties, with discussions on the deformation behaviour and failure mechanisms. Topics include elastic and plastic deformation, plastic slip, strengthening mechanisms, stress concentrations and fracture mechanisms, linear elastic fracture mechanics approach, crack initiation and	**12**	**8**

	propagation, and creep. Furthermore, the course aims to provide real-world failure case studies to emphasise the topics discussed and the performance of the material.		
MEC4134Z	**Experimental Techniques for Material Characterisation** This course presents a range of experimental techniques commonly employed in the characterisation of engineering materials. The principles, apparatus setup, operation and measurement parameters, measurement optimisation for data acquisition, and measurement analysis are explored to provide a sound understanding of materials characterisation. Topics include: sample preparation for materialography, optical microscopy apparatus and techniques, electron microscopy apparatus and techniques (SEM, TEM, EDS, and EBSD), materialography image analysis, thermodilatometry, differential scanning calorimetry, thermogravimetry, and X-ray diffraction. Throughout the course, various case studies are presented to illustrate both the potential and limitations of each technique, where complementary techniques can be employed, and the use of each technique to draw structure-property relationships.	**12**	**8**
MEC4135Z	**Experimental Techniques for Mechanical Testing** This course provides a detailed insight into the experimental techniques for determining the mechanical properties of engineering materials. The course provides an overview of commonly used mechanical testing techniques, sample preparation, metrology, measurement analysis, and statistical methods. Commonly employed testing techniques are covered, including: hardness; quasistatic (tensile, compression, and bending), impact, fracture toughness, fatigue, fatigue crack growth rate, creep, and a selection of specialized techniques. An emphasis is placed towards practical aspects of the mechanical testing procedures and techniques, and optimisation of the information acquired from the experimental results obtained.	**12**	**8**
MEC4136Z	**Functional and Contemporary Materials** This course offers an insight into a selection of functional and contemporary engineering materials. The course investigates the societal contributions and development of materials within a selection of fields and develops an understanding of sustainable materials. Throughout the course, case studies are used to demonstrate the relationships between structure-properties-processing-performance of materials in contextually driven applications.	**12**	**8**
MEC4137Z	**Microstructure and Phase Transformations in Metals** This course provides an introduction to the crystallography of metallic materials (description and representation), the	**12**	**8**

	influence of thermodynamics and kinetics on alloy phase constitution and microstructure development, solidification and solid-state phase transformations, and metal deformation and annealing phenomena.		
END5044Z	**Professional Communication Studies** This course aims to develop students' skills and understanding of the importance of effective communication within the professional environment. It provides the opportunity to consolidate practical experience and knowledge of a variety of communication formats including reports, business proposals and online platforms, applying these to the context of academic writing, including referencing. Students learn the requirements for written and oral communication in terms of planning, organisation and selection of information, as well as in terms of linguistic and oral style and final presentation. Students will have to demonstrate proficiency in both written and oral formats.	**12**	**8**
Total credits		120	

During the review period, the program was convened by Chris Woolard from 2017 to 2021, after which James Dicks took over the role in 2022 and continues to serve in this capacity. The program benefits from the collective expertise of a diverse group of academic and research staff, including (in alphabetical order) Thorsten Becker, James Dicks, Alison Gwynne-Evans, Sherlyn Gabriel, Sarah George, Nasheeta Hanief, Candace Lang, Ernesto Ismail, and Tokoloho Rampai. Their wide range of disciplinary knowledge enriches the degree program, ensuring a comprehensive and well-rounded educational experience. To further enhance the curriculum, guest lectures from industry experts are regularly incorporated. Notably, Paul Evans from Technology Strategy Consultants delivers a two-week lecture and workshop series on wrought aluminium, providing valuable industry insights. Additionally, the curriculum is strengthened by integrating research activities from industry associations, such as the Hulamin THRIP and Algaeholix THRIP projects.

Aside from BSc(Hons) Materials Science candidates, several of the courses within the degree programme are also offered as elective courses for 4th year BSc Chemical Engineering and BSc(Eng) Mechanical Engineering students and MSc(Eng) candidates from BISRU and CERECAM Centres within the Mechanical Engineering department.

3.9 Curriculum review

In 2022 and 2023, comprehensive revisions to the program curriculum were undertaken. A series of curriculum workshops and strategy meetings were held involving key stakeholders within the degree program to ensure the success of these revisions. The primary motivations for these revisions were:

- To provide a coherent and relevant programme with courses structured to improve learning and teaching.
- Ensure the programme's curriculum aligns with contemporary knowledge, skills, and values.

- To facilitate the graduate’s ability to contribute towards understanding, predicting, manipulating, and monitoring the behaviour of engineering materials through an advanced understanding of structure-property-processing-performance relationships of materials.
- To reduce the overall credit requirements from 144 credits to 120 credits to align with SAQA degree requirements.

The programme revisions were successfully approved and implemented between 2023 and 2024, resulting in a coherent, streamlined, and relevant offering aligned with contemporary knowledge, skills, and values. In 2023, the courses within the degree programme were also launched on the Amathuba online learning platform, leveraging modern and pedagogically sound learning and teaching methods.

3.10 Graduate studies and entrance into the workplace

The BSc (Hons) Materials Science degree program welcomes applicants with a BSc or equivalent degree from a diverse range of undergraduate institutions, both locally and internationally, as illustrated in Figure 1. Currently, most accepted applicants (40%) have completed their undergraduate studies at UCT, highlighting the program's role in promoting student retention within the institution. Additionally, the significant proportion of applicants from other institutions, nationally (52%) and internationally (8%), underscores the program's strong reputation and appeal across broader academic communities.

The BSc (Hons) Materials Science degree program intends to prepare candidates for both postgraduate research and entry into relevant workplaces within the Materials Science and Engineering sectors. Between 2018 and 2023, 22 graduates from the program have continued their studies at the Master’s level. This includes 6 pursuing a Master’s in Materials Engineering at UCT, 5 pursuing a Master’s in Chemical Engineering at UCT, 4 pursuing master’s degrees in other faculties at UCT, 6 pursuing master’s degrees at Stellenbosch University, and 1 pursuing a Master’s at the University of Birmingham. These outcomes highlight the program’s effectiveness in fostering student retention within CME and across the broader UCT institution at the postgraduate level.

Moreover, a significant number of BSc (Hons) Materials Science graduates have transitioned directly into the workforce (25 %) within fields related to Materials Science and Engineering. This demonstrates the program’s success in developing skilled professionals in areas identified as critical to the industry. Graduates have made meaningful contributions to several key sectors within South Africa, underscoring the program’s impact on addressing scarce skills. These include:

- Council for Scientific and Industrial Research (CSIR)
- Hulamin South Africa
- Mintek
- Columbus Stainless Steel
- National Amalgamated Packaging (Nampak)
- Bridgestone South Africa
- Sasol South Africa
- SAPPI South Africa

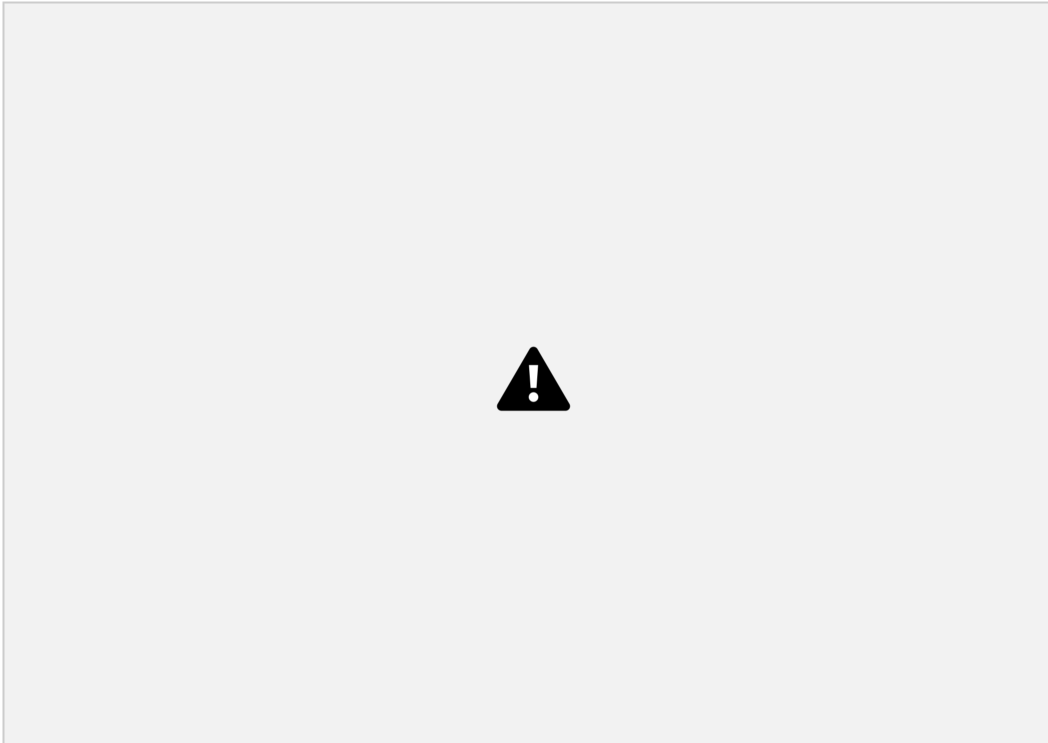

Figure 1: Intake from undergraduate institutions 2018-2024

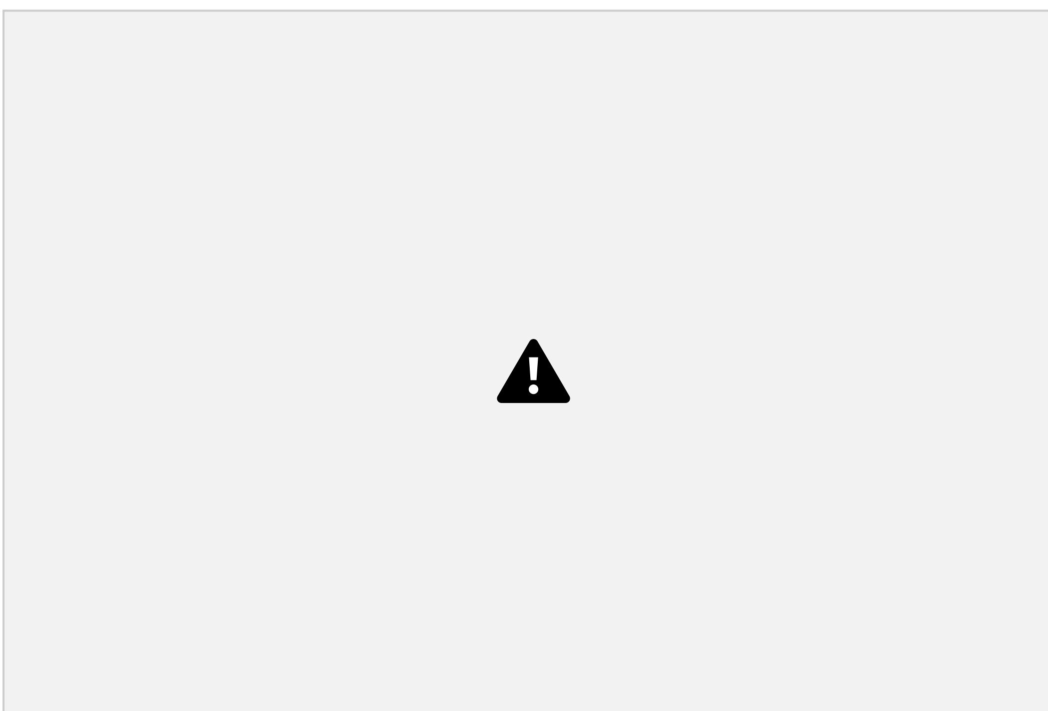

Figure 2: Graduate studies and entrance into the workplace.

3.11 Future directions

Looking towards the future, the BSc (Hons) Materials Science program is committed to continuing its growth trajectory of student intake while maintaining a high degree completion rate. This expansion will be balanced with a focus on fostering an inclusive and welcoming environment that supports all candidates' academic success.

The program also aims to continuously refine its curriculum to ensure that it remains contemporary, relevant, and aligned with the evolving needs of the field. This includes updating teaching methods, integrating diverse academic perspectives into course content, and leveraging modern learning and teaching software to enhance the educational experience.

Furthermore, the program will maintain and expand the incorporation of industry experts' input within the curriculum, ensuring that students benefit from real-world insights and connections. By strengthening ties with industry, the program aims to facilitate more graduate opportunities within the sector, helping students transition smoothly into their professional careers.

4 Research and Teaching Structures

The centre comprises research structures that support and enhance the activities of our research groups. Aligned with our mission, we aim to create a robust environment that supports innovation, interdisciplinary collaboration, and impactful research outputs.

One of the Centre's strengths lies in its well-established facilities and infrastructure, including specialised software and advanced equipment, which help our researchers explore the intricate relationships between process, structure, property, and performance across various materials. Moreover, we are dedicated to fostering interdisciplinary research and encouraging collaborations within South Africa and globally, which are vital for addressing complex materials-related challenges. Below are the critical structures CME offers to support research.

4.1 Laboratory infrastructure

Over the years, the Centre has developed a comprehensive and advanced research infrastructure, supporting the diverse research activities carried out within the Centre. Given our focus on the physical, chemical, electrical, and mechanical properties of ceramic, polymeric, metallic, and composite materials, our equipment base ranges from microscopes for investigating fine microstructures to large mechanical testing systems for evaluating material performance under various conditions.

The Centre is well-equipped with materials testing facilities, both commercially available and custom-built for specific simulation testing. To better manage the vast array of equipment, we have categorised our facilities into the following suites:

Metallographic Preparation: This suite includes equipment for preparing samples for subsequent microscopic analysis, including cutting, grinding and automatic polishing machines.

Microscopy: Our microscopy suite includes several light microscopes, including a Nikon SMZ 25 Stereo microscope, Nikon Elipse MA200 Inverted Metallurgical Microscope and a suite of Zeiss Primotech Microscopes for student practicals, and access to the electron microscope suite housed within the Electron Microscopy Unit.

Heat Treatment Furnaces: We offer a variety of furnaces designed for controlled heat treatments, which are essential for studying phase transformations and material behaviour at elevated temperatures. These include standard box furnaces, salt baths with a capacity of 140 C up to 900 C, vacuum furnaces with quenching facilities, and one vacuum furnace that can heat to 1500 C.

Thermal Analysis: This suite includes dilatometry, scanning calorimetry, and thermogravimetric analysis (TGA), enabling detailed thermal characterisation of materials.

Hardness Testing: We offer hardness testing capabilities across a wide range of loads (2g – 150kg).

Mechanical Testing: We provide a broad range of mechanical testing machines, including screw-driven testing machines with load capacities ranging from 100 N to 250 kN.

Fatigue Testing: We include two refurbished servo-hydraulic systems with 45kN and 250kN capacities. These systems offer dynamic and fatigue testing capabilities essential for understanding the mechanical performance of materials under cyclic loading. The 45kN frame is also equipped with a furnace for high-temperature testing.

Impact Testing: Our facilities include pendulum and fully instrumented drop-weight impact testing machines, which are crucial for assessing materials' toughness and impact resistance.
Corrosion Testing: Equipment dedicated to evaluating the corrosion resistance of materials under various environmental conditions.

Mini-Casting Facility: A specialised facility for small-scale casting experiments, allowing us to investigate the casting behaviour and properties of metallic materials.

Creep Testing: We possess two load-controlled creep testing rigs, which are essential for studying the long-term deformation behaviour of materials under constant load and temperature.

Thermo-Mechanical Process Simulator: Our Gleeble 3800 is a fully integrated digital closed-loop control system, recently upgraded through an NRF-NEP grant to include state-of-the-art induction heating and a digital image correlation system. The system allows direct resistance and induction heating with rates up to 10 000 °C/sec and maintains steady-state equilibrium temperatures. It is also equipped for high cooling rates, enabling quenching after testing. The mechanical system features a servo-hydraulic system capable of exerting up to 200 kN in compression and 100 kN in tension, with displacement rates as fast as 2000 mm/sec. Our configuration allows for the close simulation of industrial metal processes such as hot rolling, forging, and extrusion, enhanced by the HYDRAWEDGE module. Additionally, the system supports high-speed heat treatments and welding simulation, making it an invaluable tool for phase transformation studies and advanced materials processing research.

Digital image correlation: We have several digital image correlation systems (MatchID and Dantec), including planer and stereo vision camera setups. We also have a range of digital cameras and lenses that allow a large field of view. Digital volume correlations are performed using volume data from an industrial X-ray micro-computed tomography facility through the Central Analytical Facilities at Stellenbosch University.

4.2 Computational infrastructure

The CME has a computational infrastructure to support our research and teaching activities. We use specialised software tools to cater to the needs of our research community. Our laboratory infrastructure often includes measurement software for analysing tensile test data, conducting fracture toughness tests, investigating fatigue crack growth rate, and performing impact energy analysis. Additionally, we utilise industry-leading software like MatchID, Danntec, and LaVision for digital image and volume correlation.

In our optical microscopes, we use specialised software for microstructure analysis. For scanning electron microscopy, specifically crystallographic and texture analysis, we rely on open-source software such as MTEX and ATEX and have access to AZtecCrystal through the EMU.

ThermoCalc is a sophisticated thermodynamic modelling and simulation tool critical to materials science research. We also utilise advanced modelling and simulation tools in collaboration with CERECAM, such as Ansys, for finite element analysis and simulation.

Matlab, available through a campus-wide license, is used for numerical computing. We extensively use Origin for data analysis and visualisation and Python for scripting, data manipulation, and various computational tasks. Additionally, we provide access to StatEase for complex statistical analysis, aiding in the design of experiments and data interpretation.

We have dedicated high-performance workstations for computationally intensive analyses and simulations. These machines are essential for handling large datasets and running complex simulations. We also provide access to Computer-Aided Design (CAD) software.

CES EduPack is available to support selecting and analysing materials for our educational activities.

4.3 Sustaining an active research culture

The Centre is research-focused, fostering a dynamic and engaged research community comprised of academic staff and postgraduate students at the BSc(Hons), MSc(Eng), and Doctoral levels. Our commitment to maintaining an active and vital research culture is reflected in several key practices:

Weekly Research Seminars: The Centre hosts seminars every Thursday during the meridian, followed by informal interactions and discussions. These seminars are an integral part of our research culture, with attendance and active participation expected from everyone. The seminars are presented either by postgraduate students or academic staff. Masters and Doctoral students typically give one or two 45-minute seminars per year, while Honours students present one 10-minute seminar and one 20-minute seminar on their research projects.

Conference Participation: Postgraduate students preparing to present papers at conferences are encouraged to give “run-through” seminars. This practice allows them to inform colleagues about their work and receive constructive feedback. Masters students typically attend one or two South African conferences during their two-year registration period, where they present their research findings. Doctoral students are expected to make at least one international visit during their studies, either to work in a laboratory or present a paper at an international conference.

Conference Proceedings and Journal Papers: Preparing research papers for conference publication and presentation is a continuous activity at CME. Published papers are prominently displayed within the Centre, emphasising our commitment to high-impact research dissemination. To uphold high standards, an annual award is presented to the postgraduate student who publishes the best paper in an accredited journal.

4.4 Interdisciplinary and collaborative research

The Centre operates on an “open-door” policy, welcoming researchers and students who require access to materials and research expertise. While we strive to ensure cost recovery wherever possible, this approach allows us to assist numerous researchers from outside the Centre in utilising our equipment and interpreting materials analysis. Often, these interactions lead to the initiation of collaborative research projects as they develop further. The Centre is committed to supporting collaborative research activities within the Mechanical Engineering Department.

CME actively engages in strong collaborative research activities in South Africa and internationally. Our local partnerships include esteemed institutions such as Stellenbosch University (SU), the Central University of Technology (CUT), North-West University (NWU), Nelson Mandela University (NMU), and the Council for Scientific and Industrial Research (CSIR). Internationally, our collaborations extend to prominent institutions such as the Norwegian University of Science and Technology (NTNU), Nanyang Technological University (NTU), the Swiss Federal Institute of Technology Zurich (ETH Zurich), Delft University of Technology (TU Delft), Katholieke Universiteit (KU) Leuven, Oxford University, the National Physical Laboratory (NPL) in the United Kingdom, Ohio State University, and Eindhoven University of Technology (TU/e). Specific details of these collaborations can be made with reference to the individual research groupings in Section 4.

5 OUTPUTS

The Centre's research outputs are measured against formal publication metrics, the successful qualification of students for higher degrees, and the extent of our engagement with the local and global industry sectors. Below, we summarise the outputs across our Honours, MSc (Eng), PhD programmes, publication outputs, and our engagement with industry.

5.1 Honours programme

Between 2018 and 2024, the student intake and an overall high degree completion rate have remained successful, as shown in Figure 3. Although student intake numbers declined during the COVID period, subsequent steady growth in numbers has occurred. Efforts are ongoing to continue growing the student intake, focusing on disseminating the degree programme offering over digital media and seeking bursary opportunities for accepted applicants.

Over the review period, CME has graduated 51 Honours students with an 83% pass rate. The honours programme is fully transformed, with a nearly equal split between female and male students and 90 % contributing from underrepresented groups, including African, Coloured, and Indian backgrounds.

A strong focus is placed on integrating the BSc (Hons) Materials Science candidates within the research activities and postgraduate cohort within the Centre for Materials Engineering. This has been achieved by aligning the Research Project (MEC4091Z) to the current research activities and postgraduate projects and attending and participating in weekly research seminars, thus providing students with an opportunity to engage and contribute towards the current research at the Centre for Materials Engineering. Secondly, the academic staff and class representatives have promoted integration between the postgraduate cohort and BSc (Hons) candidates through regular social activities. These activities have been found to foster an inclusive and welcoming environment that promotes engagement between the students.

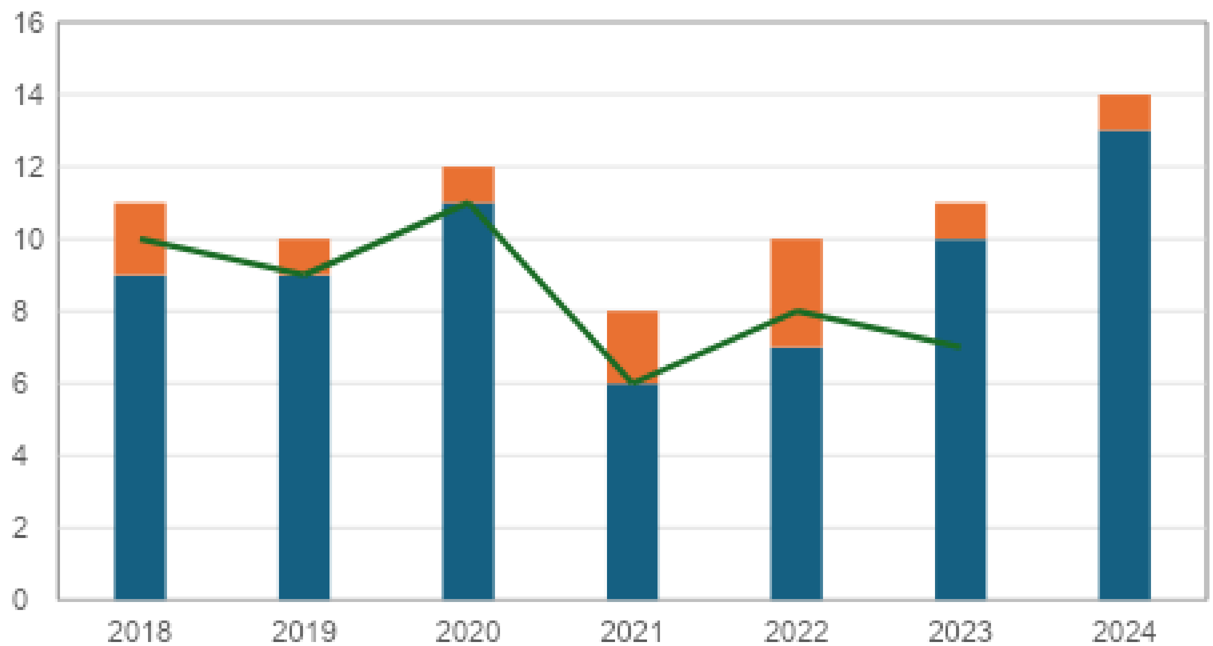

Figure 3: Student intake and degree completion 2018-2024

5.2 MSc (Eng) and PhD cohort

The Centre is proud to host three postdoctoral fellows (see appendices) and has successfully graduated 2 PhD and 21 MSc (Eng) candidates during the review period (see appendices). Over the past four years, we have seen a significant increase in postgraduate engagement, with 17 MSc (Eng) and 8 PhD candidates currently pursuing their research within the Centre.

The Centre also benefits from strong partnerships with other universities, including Stellenbosch University, where 2 MEng and 3 PhD candidates actively engage in research activities within our laboratory as part of their postgraduate studies. These collaborations enhance our research capacity and contribute to a richer academic environment.

A key aspect of our growth is the increasing diversity within our student body. Half of our MSc (Eng) and PhD students are female, and 69% come from underrepresented groups, including African, Coloured, and Indian backgrounds. This progress reflects our commitment to transformation and inclusivity, bringing us closer to aligning with UCT's target of achieving 80% representation from these groups.

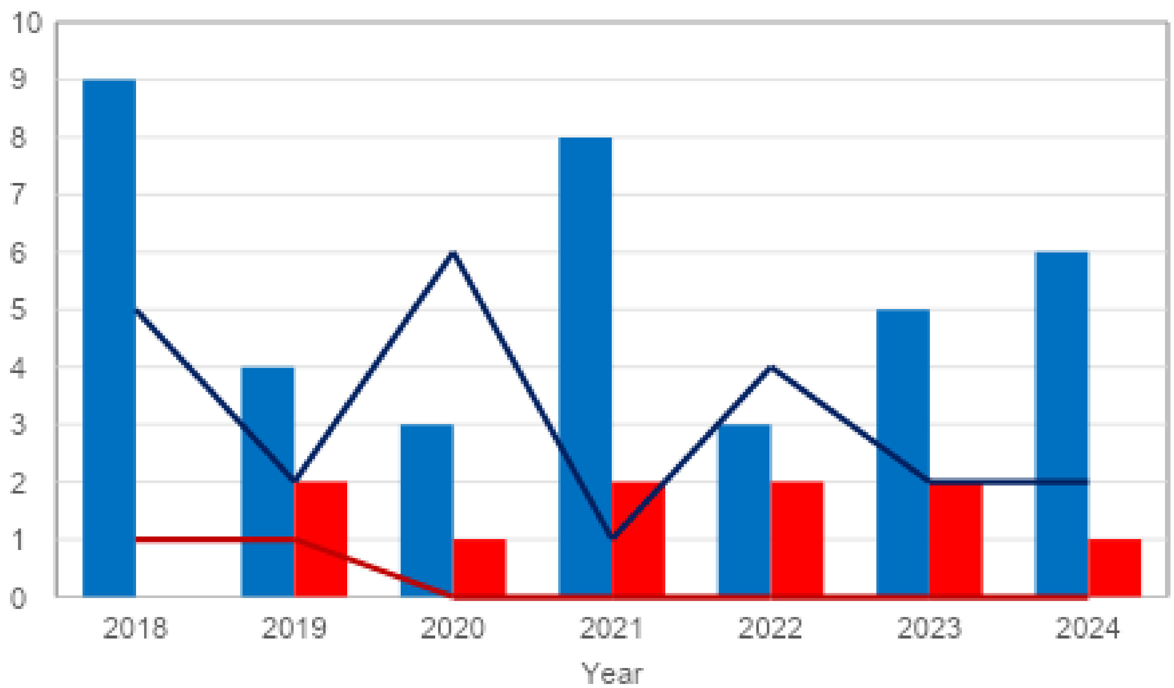

Figure 4: Infographic of MSc (Eng) and PhD intake and graduations.

One of the key challenges we face is student throughput and the time taken from registration to graduation. Over the review period, the median time required to complete an MSc degree within the Centre has been three years. For PhD candidates, although we had only a few graduations (2) during this period, preliminary data suggests that the time to graduation is typically around five years. While these durations exceed the expected timelines, they are not unusual for degrees in Science and Engineering. It is also important to note that the time recorded often includes the period between the submission of the thesis, the examination process, and the final graduation, which can add six months to a year to the overall timeline. In addition, since the degrees are project-based, the students registered during the COVID period were hugely disadvantaged since the laboratory was closed for an extended time and took longer than expected to complete their practical experiments. Despite these factors, we are actively working towards reducing the time to graduation, particularly for our MSc degrees, to bring the completion time closer to the expected two-year period.

5.3 Publications

Formal research publications and presentations are listed in the appendices. Of the 23 journal papers, 12 Conference proceedings and 19 conference articles or extended abstracts in non-accredited, non-peer-reviewed professional bodies. Notably, our research has been published in Q1 international Materials Science and Engineering journals, such as *Acta Materialia*, *Materials Characterization*, *Polymers*, *Biotribology*, and the *Journal of the Mechanics and Physics of Solids*. Our work has also been presented at prestigious international conferences, including the *TMS Annual Meeting & Exhibition* and the *International Conference on Advances in High-Temperature Materials*. Locally, we have contributed to conferences such as the annual *RAPDASA-RobMech-PRASA-CoSAAMI* conference. Our publication record reflects the diverse range of disciplines published by our Centre. The collaborative nature of our research is evident, with most of our outputs being co-authored by colleagues from partnering local and international institutions, as highlighted in Section 4.

Below is an infographic illustrating our yearly publication outputs. There has been a significant increase in the publication outputs, including 28 outputs over the last 2.5 years. While these outputs are commendable, given the size of our academic staff and the number of postgraduate students, we recognise room for improvement. Balancing administrative duties, teaching responsibilities, and research activities remains an ongoing challenge, particularly for our relatively young academic cohort, who are still building their research profiles. We are implementing ongoing efforts to facilitate increased research outputs to address this. We continuously foster a culture of continual quality publication, aiming to enhance the Centre's academic standing further and contribute more significantly to the body of knowledge in Materials Science and Engineering.

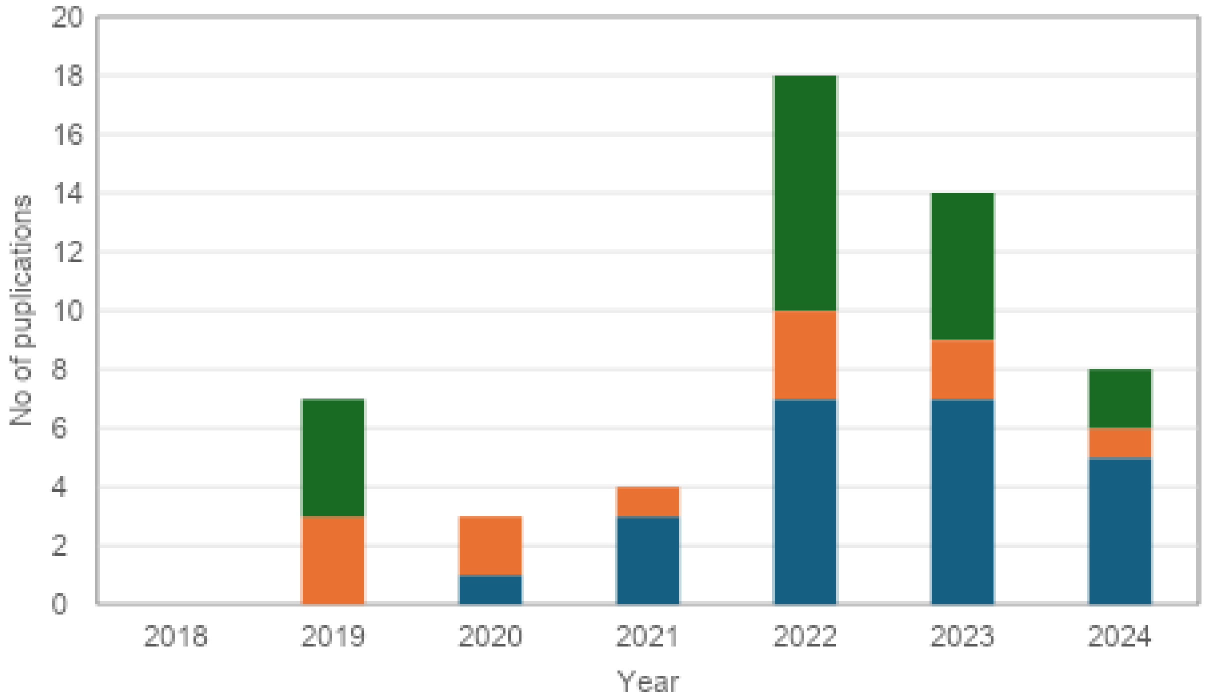

Figure 5: Infographic of publication outputs over the review period.

5.4 Industry support

5.4.1 Hulamin

CME has played a pivotal role in supporting Hulamin Rolled Products, a key contributor to South Africa's aluminium industry. Over the past 25 years, CME has collaborated closely with Hulamin to advance the field of wrought aluminium products and processes, establishing itself as the leading research centre in this area within the country. Through this partnership, CME has undertaken numerous postgraduate projects at Honours, MSc, and PhD levels, contributing to developing cutting-edge techniques and hardware for aluminium process simulation and material analysis.

Recognising the critical need for immediate technological support in the aluminium industry, CME has recently intensified its collaboration with Hulamin to address specific technical challenges that Hulamin faces in its manufacturing processes. CME provides targeted support through a variety of initiatives:

- **Technical assistance**

  The Centre engages in short to medium-term projects carried out by contracted postgraduate staff and MSc students to provide Hulamin with solutions to pressing technical issues. These projects are designed to deliver results within realistic time frames, ensuring that Hulamin can address manufacturing challenges efficiently.

- **Industrially relevant, applied and fundamental research**

  Through dtic, THRIP-supported collaboration with Hulamin, the Centre is committed to maintaining industrial relevance when scoping longer-term research projects to generate fundamental and applied knowledge and technology advancements that underpin the drive for innovation in various aspects of the aluminium ecosystem. These projects contribute to Hulamin's industrial needs through process optimisation, alloy, and process development, and they add human capacity in the area of aluminium through MSc and PhD degrees, as well as up-skilling of Hulamin staff.

- **Driving innovation**

  The Centre supports Hulamin in collaborative, industrially relevant research projects that can lead to multi-level benefits for Hulamin. These include the application of the primary research findings in current practices or as new products and knowledge building, which supports re-engineering and optimisation, thus driving innovation in the area of rolled aluminium. Innovation is the driver for optimisation, improved productivity and new business development.

- **Training and education**

  The Centre actively contributes to the upskilling of Hulamin's technical staff by involving them in process simulation and material characterisation during technical assistance projects. Furthermore, CME offers opportunities for Hulamin staff to pursue higher degrees in aluminium-related research, fostering ongoing education and skill development.

5.4.2 Eskom EPPEI

CME has supported Eskom through its Materials and Mechanics Specialisation, a core component of the Eskom Power Plant Engineering Institute (EPPEI). This specialisation's principal objectives are to advance knowledge in materials science and mechanics relevant to power generation and to provide a robust research platform that promotes the education and skill development of postgraduate candidates, thereby elevating the technical expertise of Eskom engineers.

CME's collaboration with Eskom has focused on seven critical areas identified in partnership with Eskom, including physical metallurgy and metallography, structural integrity, high-temperature behaviour, environmental degradation, welding metallurgy, materials modelling, and non-destructive evaluation (NDE). Through this partnership, CME has contributed to research in power plant steels, addressing challenges such as creep life estimation, high-temperature material damage assessment, small sample and small punch testing, and weldment strain localisation.

5.4.3 Mintek

CME partnered with Mintek to improve material durability and performance testing capabilities. We have conducted specialised training on fracture toughness testing and testing protocols. This involved delivering a three-day fracture toughness testing course to Mintek staff, providing them with the skills needed to perform thorough evaluations.

CME also collaborates with Mintek focusing on the hot rolling of aluminium to simulate rough rolling, which forms part of an ongoing drive to simulate the full industrial rolling practice on a lab scale.

5.4.4 Sasol

CME has worked with Sasol to improve safety standards by conducting advanced fatigue and fracture toughness testing. Our services have helped enhance Sasol's safety protocols by evaluating critical components for durability and reliability. Our ongoing work on in-situ strain mapping using DIC has also improved piping strain analysis capabilities. This collaboration is anticipated to bring significant cost savings to Sasol, as these analyses can now be performed in-house, eliminating the need for external services.

5.4.5 DSI Gleeble (United States of America)

CME has partnered with DSI Gleeble, a leader in thermomechanical simulator products. This collaboration involves the development of testing protocols and test fixtures that enhance the capabilities of their flagship Gleeble thermomechanical simulators. The partnership is mutually beneficial, placing DSI at the forefront of research conducted at CME while providing us with direct access to the equipment manufacturer. This close relationship facilitates the development of new and innovative testing methods. Additionally, DSI Gleeble has recognised the value of our graduates by employing one of them part-time while also supporting the running costs within the Centre, further strengthening the collaboration.

5.4.6 EOS GmbH (Germany)

CME has partnered with EOS GmbH in Germany to investigate the fatigue and fracture properties of AlSi10Mg produced through additive manufacturing (AM). This collaboration has enhanced our understanding of the mechanical behaviour of 3D-printed materials and provided valuable insights into the field of AM. The research outcomes from this partnership will benefit our academic pursuits and provide EOS with critical data to improve its material development processes.

5.4.7 MatchID (Belgium)

CME has also formed a productive collaboration with MatchID in Belgium, focusing on developing methods to extract fracture properties from DIC data. This partnership has allowed us to refine analytical techniques that advance modern metrology technologies. By working closely with MatchID, we have contributed to the evolution of DIC methodologies, ensuring that these tools remain at the cutting edge of materials analysis.

6 Governance

6.1 Personnel

CME currently comprises nine academic members that form part of the various research groupings in the Centre. These positions are funded by the General Operating Budget (GOB). Seven of these staff members are part of the Department of Mechanical Engineering, while two, Nasheeta Hanief and Robert Knutsen, are affiliated with the Electron Microscopy Unit (EMU). Additionally, we are fortunate to benefit from the expertise of Emeritus Professors Candace Lang and Robert Tait, who continue contributing to our team. As of 2022, the Centre's leadership includes Thorsten Becker as Director, Sarah George as Deputy Director and James Dicks as the Honours Program Convenor.

The Centre employs Penny Louw as the Senior Technical Officer, providing essential (and ever-growing) administrative support and overseeing operations in our laboratory. In addition, Gerard Letaba is employed by the Centre as a Research Officer, specialising in microscopy work that supports our research efforts. To further assist with day-to-day activities and facilitate experimental work, we appoint laboratory engineers, who will be postgraduate students who contribute their skills and knowledge to maintain the lab's functionality.

Leadership

- Thorsten H Becker, BSc (Eng) PhD *Cape Town* (Director)
  https://ebe.uct.ac.za/department-mechanical-engineering/contacts/thorsten-becker
- Sarah L George, BSc (Eng) MSc (Eng) PhD *Cape Town* (Deputy Director)
  https://ebe.uct.ac.za/department-mechanical-engineering/contacts/sarah-george
- James A Dicks, BSc (Chem, EGS), BSc (Hons), MSc (Eng) *Cape Town* (Honours Program Convenor)
  https://ebe.uct.ac.za/department-mechanical-engineering/contacts/james-dicks

Associated Academic staff

- Sherlyn Gabriel BSc (Eng) MSc (Eng) PhD *Cape Town*
  https://ebe.uct.ac.za/department-mechanical-engineering/contacts/sherlyn-gabriel
- Nasheeta Hanief BSc MSc (Eng) PhD *Cape Town*
  https://ebe.uct.ac.za/emu/about-us/about-our-staff
- James Hepworth BSc (Eng) MSc (Eng) *Cape Town*
- https://ebe.uct.ac.za/department-mechanical-engineering/contacts/james-hepworth
- Wei Hua Ho, BSc(Eng)(Honours) *Nanyang Technological University* PhD *Canterbury*
  https://ebe.uct.ac.za/department-mechanical-engineering/contacts/wei-hua-ho
- Ernesto Ismail BSc (Eng) MSc (Eng) *Cape Town*
  https://ebe.uct.ac.za/department-mechanical-engineering/contacts/ernesto-ismail
- Robert D Knutsen, BSc PhD *Cape Town*
  https://ebe.uct.ac.za/emu/about-us/about-our-staff

Emeritus Professors

- Candace Lang BSc PhD *Cape Town*
- Robert B Tait PrEng BSc (Hons) Rhodes MA *Oxon* BSc (Eng) PhD *Cape Town*

Technical and Research Officers

- Penny Louw NHD (Metallurgy) *Wits Tech* BSc (Hons) *Cape Town*
- Gerard Letaba BSc (BioChem), BSc(Hons) MSc (Eng), PhD (Eng) *Cape Town*

Finance officer

- Shane Ferguson

Lab engineers

- David Dallas BSc (Eng) *Cape Town*
- Sabrina Rudolph MEng *Stellenbosch*
- Khombisile Simelane BSc (Eng) *Taiwan* MSc (Geoscience) *Luleå* MSc (Eng) *Liege*
- Maxwell Vos BSc (Eng) *Cape Town*

Visiting Lecturers

- Paul Evans, BA (Nat Sci) *Cambridge* PhD *Cambridge*
- Melody Neaves BSc (Eng) MSc (Eng) PhD *Stellenbosch*
- Natasha Sacks BSc (Eng) MSc (Eng) *UCT* PhD *Friedrich Alexander*
- Johan Westraadt BSc (Physics) PhD Physics, MBA *Nelson Mandela*
- Chris Woolard BSc (Chem) MSc (Chem) PhD *Cape Town*

Table 2 summarises the number of publications, citations, and h-index values for CME academic members, as obtained from Scopus. The summary highlights diverse research impacts, reflecting the varying stages of career development among our members, from established researchers to early career academics. We are fortunate to have two Emeritus Professors continue to enhance our academic profile and contribute to our publication output.

It is important to note that many of our members are young and emerging academics who are still building their academic footprint and impact. We are confident that, over time, these profiles will grow, further enhancing the Centre's footprint and research impact.

Table 2: Personal citation metrics in alphabetical order (total career numbers). Obtained from Scopus, August 2024

	No of recorded outputs	**Citations**	**H-index**
Thorsten Becker	59	1 374	23
James Dicks	1	6	1
Sherlyn Gabriel	8	27	3
Sarah George	9	43	3
Nasheeta Hanief	5	8	2
James Hepworth	3	2	1
Wei Hua Ho	31	308	8
Ernesto Ismail	3	21	2

Robert Knutsen	47	1 222	14
Candace Lang	74	1 585	21
Robert Tait	35	786	15

6.2 Succession planning

Our academic members, primarily employed within the Department of Mechanical Engineering, develop and supervise the centre's core activities. Consequently, CME-associated academics are responsible for delivering undergraduate and postgraduate programs, supervising postgraduate research, and managing administrative tasks for the Department and the Centre.

The success of the Centre is undoubtedly due to the dedicated commitment of a few core academic staff members. One of the main challenges we face is the need for more administrative assistance from the University. Currently, our support staff positions are soft-funded, making them highly dependent on the availability of external funding and the goodwill of CME's associated academics. This reliance on variable financing underscores the importance of having more stable support to sustain the Centre's administrative and operational needs.

Despite these challenges, we are fortunate to receive valuable and critical input from several visiting and part-time lecturers who contribute to the BSc (Hons) program and co-supervise postgraduate research students. The Centre has experienced significant growth over the past two years, with several new academic members joining the team. We are excited about these developments and look forward to the new directions these additions will bring to our research focus areas. Currently, no staff members are planning to leave in the near future, so we have yet to make provisions for a succession plan. However, should there be a change in leadership, the Centre is now well-positioned to manage such transitions effectively.

6.3 Organisational structure and governance

The organisational structure of CME is designed to ensure the efficient management of the Centre's activities. The success of CME is attributed to the dedication and commitment of its leadership and support staff, supported by the valuable contributions of associated academics and visiting and part-time lecturers who enhance our teaching and research capacity.

CME's governance framework is structured around a series of regular meetings that facilitate ongoing dialogue, strategic planning, and coordination across all aspects of the Centre's operations:

Weekly governance meetings: These meetings provide a platform for discussing administrative matters related to our daily activities. The meeting members include CME's leadership, support staff, and laboratory engineering. The weekly schedule enables timely decision-making and ensures the efficient running of the Centre's operations.

Monthly Research Meetings: These meetings are led by the heads of the research groups, who bring together associated academics to discuss ongoing projects, share updates, and coordinate efforts across the various research activities within the Centre. The focus is on sharing progress in research activities, publication outputs, conference attendance, funding requirements, and future planned activities. During these meetings, we also discuss financial matters, including the current financial status, operational costs, possible funding requirements, and open funding calls.

Monthly Honours Meetings: Led by the Honours Program Convenor, these meetings focus on the administration and coordination of the BSc (Hons) program. Course convenors discuss the current courses, highlighting successes and challenges. Also included are student representatives to bring attention to issues in the current program.

Annual Research Strategy Workshop: A key event in CME's calendar, this workshop brings together *all* academic staff to reflect on the Centre's research achievements and to develop a strategic plan for the upcoming year. The workshop facilitates long-term planning, identifies emerging research opportunities, and sets the direction for future research initiatives.

Last, the Centre encourages interaction through Research Seminars, a fundamental part of CME's research culture. These weekly sessions take place during term time and feature presentations from both internal and external researchers. We invite academics from partner universities nationally and internationally to share their research. Additionally, we ask our associate academic staff members to present their diverse research within the centre. The seminars also provide a platform for postgraduate students to showcase their work. Typically, Masters and PhD students present their research progress and may also share the talk for an upcoming conference presentation. We promote these seminars to our collaborators, such as Stellenbosch University, by facilitating online participation.

6.4 Financial sustainability

The Centre has shown financial sustainability, operating without incurring losses. This stability is mainly due to the Centre's strategic financial management and reliance on its research groups with long-term funders. Smaller groups within CME have also been fortunate enough to enjoy support through the Universities Research Committee.

CME has established several dedicated funds to support its diverse research activities that address specific operational needs. These funds include:

- **Consumables Fund**

  This fund is designed to cover the costs associated with testing materials and consumables. The fund ensures that students and researchers have the necessary resources at their disposal. We typically request a contribution per student/project per year.

- **Mechanical Testing Fund**

  A separate fund has been allocated specifically for the maintenance and operation of mechanical testing equipment. The fund ensures that the Centre's advanced testing facilities remain in good working order. We typically request a contribution per student/project per year.

- **Gleeble Fund**

  Testing on the Gleeble thermomechanical simulator is significantly more expensive, so it has its dedicated fund. The fund covers the costs of maintenance and operational needs. We typically request a contribution per student/project per year.

- **Miscellaneous fund**

  We include a miscellaneous fund that is funded through consulting activities in the Centre. The fund is used at the Centre's discretion, mostly supporting kitchen consumables, including milk, tea, coffee, and, occasionally, end-of-year entertainment functions.

- **Support Staff Salaries Fund**

  Recognising the importance of administrative, teaching, and technical support, CME has set up a fund to cover the salaries of its support staff. The fund ensures that the Centre can maintain the necessary level of support to facilitate its research and educational activities.

7 Conclusion

7.1 Current Status

CME continues to stand as a pillar of excellence in Materials Science and Engineering in South Africa, reflecting its historical strengths while embracing new challenges and opportunities. CME has continued to strengthen its research agenda, particularly in metallic materials, including aluminium and titanium, which align with the industrial needs of South Africa. The strategic focus on these materials has enabled sustained partnerships with key industry players such as Hulamin, ensuring that CME's research remains relevant and impactful. The Centre has also broadened its research scope by incorporating new areas of study such as bio-based polymers, composites, and renewable materials. This expansion has been supported by the addition of Associated Academics with diverse expertise, leading to the establishment of several new research groupings. These efforts underscore CME's commitment to strategically responding to emerging research opportunities and industry needs.

We maintain a student-centric research philosophy, prioritising the acquisition of funding from sources such as the University funding opportunities, Governmental funding agencies such as the National Research Foundation, the Department of Science and Innovation, and the Department of Trade and Industry, industrial sponsorships and international funding bodies. This approach is designed to support postgraduate students and cover associated research costs rather than focusing on recruiting dedicated research personnel for industrial projects. We aim to secure sufficient funding to support a robust cohort of postgraduate students, enabling the production of international-quality research and the development of highly trained professionals.

The Honours program seems to be unique because it focuses on enhancing the skills of science graduates to become materials scientists. As the South African government has identified materials science as a scarce skill, this program aims to provide the necessary human capital to meet this demand. Completing this qualification also improves a candidate's chances of employment, particularly in the manufacturing sector. Importantly, it also creates a pathway for further qualifications at the master's or PhD level in the Engineering faculty, specifically in Materials Engineering, further contributing to our research efforts.

In the past three years, our publication outputs have significantly increased, demonstrating the Centre's dedication to disseminating high-quality research despite the challenges posed by administrative and teaching workloads on staff. The Centre has also enlarged its PhD cohort, acknowledging that additional research capacity is essential for sustaining and enhancing its academic impact. Despite several attempts to secure additional postdoctoral funding, the current climate presents persistent obstacles, which the Centre continues to navigate.

Despite our track record of success, uncertainties remain in planning research activities; industrial support, particularly from the manufacturing sector's small- to medium-sized enterprises, is often variable and can hinder long-term planning and student recruitment efforts. Although we consistently attract NRF support, the funding levels often need to be increased to fully cover scholarships and running costs, necessitating additional efforts to secure industrial partnerships. Consequently, obtaining funding from government agencies will continue to be a priority in sustaining our research activities.

We also actively engage with industry partners to provide valuable contributions and outputs. We see this as critical and as a "service to industry." The benefit is mutual; while the industry is on the pulse of cutting-edge research, we remain grounded and industry-relevant.

Overall, the Centre is in a strong position. We have ongoing efforts to expand its research scope, increase publication output, and strengthen governance structures to demonstrate a commitment to continuous improvement. These efforts ensure that the CME remains a vital and sustainable entity within the university and the broader research community, poised to contribute to Materials Science and Engineering in South Africa and beyond.

7.2 Challenges

One of the ongoing challenges is ensuring financial stability. With the South African economy experiencing contraction, there has been a reduction in funding from governmental institutions, which has naturally affected the Centre's ability to expand its research activities. Similarly, industry funding has also seen a decline, particularly within the manufacturing sector. Although we are fortunate to have students supported through various bursary systems, our work is primarily experimental in nature. Covering running costs can be challenging with the growing complexity of testing and analysis tools. Despite these challenges, CME has proactively engaged with the University, government institutions, small and medium-sized enterprises (SMEs), and larger industrial partners to facilitate research funding. However, given the current economic climate, securing long-term commitments has been more difficult, especially for SMEs facing financial pressures.

Another important challenge to highlight is the role of the Centre within the department and the University as a whole. The Centre supports a wide range of activities that expand beyond our footprint and continue to grow, extending beyond the Department of Mechanical Engineering and EBE Faculty, and with increasing requests from other UCT faculties and South African universities; we often receive requests for access to CME's specialised testing facilities and expertise. Although the Centre makes a concerted effort to facilitate such requests effectively, the reliance on soft-funded support staff does present a considerable challenge. When staffing resources are stretched, motivating for time on non-core activities becomes hard. It is apparent that UCT is in need of an institutionally funded testing facility such as CME.

Moreover, maintaining sophisticated equipment and keeping software up to date (particularly with Microsoft's new operating system releases) are also areas that require ongoing attention. While the university provides support, more structured funding is needed to update software on equipment that is otherwise in running order. Software upgrade costs to otherwise perfectly functioning equipment can be in the millions of Rands.

Lastly, there is a recognised need to increase the number of postdoctoral researchers at CME. Postdocoral researchers contribute significantly to research productivity and innovation, and while CME continues to attract talented individuals, securing additional funding to expand this cohort would further enhance the Centre's capacity to deliver high-impact research. We have secured postdoctoral financing through the Hulamin and THRIP funding and are actively pursuing appointments for these posts.

7.3 Reflection on the previous report

Reflecting on the previous report, it is evident that our Centre has maintained a robust position within its research landscape while addressing several areas for improvement highlighted by the review. The review commended the Centre's coherent research agenda, particularly its focus on metallic materials such as aluminium, titanium, and steels. This alignment with industrial needs, exemplified by partnerships with entities like Hulamin, underscores the Centre's relevance and impact. However, the review also raised concerns about the potential risks of broadening the research scope without adequate staffing and strategic planning. Since then, we have made a concerted effort to expand our academic portfolio by adding associated academics with diverse research expertise, ranging from bio-based polymers to composites and renewable materials. We have established several research groups in these fields, demonstrating our commitment to broadening our activities strategically.

Another significant point of reflection relates to the Centre's research output. While the review acknowledged the challenges of publishing high-quality work, particularly in a student-centred research environment, it encouraged the Centre to convert more of its dissertation outputs into journal articles. We have made concerted efforts in this regard, particularly reflecting on the increase in publication outputs since 2022. However, it remains an ongoing challenge, exacerbated by staff members who are often overloaded with administrative and teaching duties. With this in mind, we aim to grow our postdoctoral cohort, but securing funding for these positions remains challenging in the current funding climate.

Lastly, the review highlighted the need for a clearer articulation of the Centre's governance and management structures. The Centre has responded by formalising its governance processes, including establishing clear Terms of Reference (see Section 10) that outline its governance structures. Since 2022, we have made significant efforts to restructure the CME's financial framework, including targeted funds for specific activities within the Centre, such as soft-funded administrative and teaching support posts, consumables funds, and repair and maintenance funds. These initiatives aim to ensure financial sustainability, enhance transparency, and make the Centre's decision-making processes more visible and structured.

In summary, the reflection on the previous report reveals a Centre that is both reflective and responsive, keen on maintaining its strengths while strategically addressing areas of concern. The Centre's actions demonstrate a commitment to continuous improvement, ensuring it remains a vital and sustainable entity within the university and the broader research community.

7.4 Future Research Directions

South Africa has a significant need for expertise in materials science and engineering, especially in the manufacturing sector. We view this as an opportunity to enhance our capabilities, expand our influence, and establish ourselves as a major player in addressing this demand.

To accomplish this, we intend to expand our facilities. This expansion will bolster our capacity to conduct groundbreaking research and maintain our competitive advantage. It will also position the Centre as a leader in providing advanced experimental capabilities essential for academic research and industrial applications. As part of this effort, establishing a strong network of facilities through collaborations with institutions such as Stellenbosch University, the

High-Resolution Transmission Electron Microscopy (HRTEM) Centre, and Mintek will be crucial for establishing comprehensive experimental testing capabilities. These collaborations will strengthen our research capabilities, promote interdisciplinary projects, and create synergies that drive innovation and discovery in materials science.

We are dedicated to developing materials and processes that enhance performance and contribute to a sustainable future. Our research is focused on creating materials with minimal environmental impact. By prioritising sustainability, we aim to support South Africa's manufacturing industry in becoming more environmentally responsible, ensuring long-term benefits for society and the planet.

Our long-term goal is to become the national materials science and engineering leader. By continuously enhancing our research capabilities, expanding our facilities, and fostering strong industry partnerships, we aim to establish a reputation for excellence and innovation. This leadership position will enable us to influence national research agendas and attract top talent and resources.

Finally, building on the success of our research in aluminium through the ARG, we propose establishing an Aluminium Centre of Excellence at UCT. This centre will concentrate on driving research and development in the aluminium industry, emphasising innovation, sustainability, and economic growth. The centre will collaborate with CME and serve as a hub for advanced knowledge generation, skilled personnel training, and industry-led research that balances industrial relevance with cutting-edge scientific discovery. Sarah George has initiated discussions with the NRF and the DSI to propose the establishment of such a Centre of Excellence.

8 Term of reference

The Centre of Materials Engineering (CME) at the University of Cape Town (UCT) is committed to advancing research, education, and innovation in materials science and engineering. This document outlines CME's mandate, strategic objectives, and governance to ensure effective collaboration and impactful research.

CME aims to:

- *Advance Materials Science and Engineering:* Conduct cutting-edge research to understand and innovate within the materials engineering tetrahedron, linking process, structure, property, and performance.
- *Support Industry:* Develop and apply materials solutions that enhance the competitiveness and sustainability of the South African materials science and manufacturing industry.
- *Foster Collaboration:* Promote interdisciplinary research and partnerships with academia, industry, and government to address complex materials-related challenges.
- *Enhance Education:* Provide high-quality education and training to develop the next generation of materials engineers and scientists in South Africa and abroad.
- *Drive Innovation:* Translate research findings into practical applications and technological advancements that benefit society and the environment.
- *Promote Inclusivity:* Attract and nurture diverse talent, ensuring equitable opportunities and representation within the field of materials engineering.
-

CME's Strategic Objectives are:

- *Advance Collaborative Research:* Foster interdisciplinary research within UCT and with external partners to drive innovation in materials science and engineering.
- *Support National Priorities:* Align research with strategic national and industry needs to enhance South Africa's manufacturing competitiveness and materials performance.
- *Publish High-Impact Research:* Translate research outputs into high-quality publications in top-tier journals and conferences, disseminating findings to the broader scientific community and industry stakeholders.
- *Attract and Develop Talent:* Draw high-quality postgraduate students and postdoctoral fellows from diverse backgrounds, promoting inclusivity and representation of South African and African society.
- *Enhance Infrastructure:* Provide state-of-the-art workspaces and research facilities to support cutting-edge research and collaboration.
- *Secure Funding:* Obtain financial support from government, industry, international, and university sources to sustain and expand CME's research activities.
- *Contribute to Education:* Support undergraduate and postgraduate teaching, promoting awareness and interest in materials science and engineering.
- *Conduct Ethical Research*: Uphold high standards of ethics in research, ensuring that all activities contribute to positive societal and environmental advancements.
- *Align with EBE and UCT Vision 2030*: Work towards the Engineering & the Built Environment (EBE) Faculty's vision and UCT Vision 2030, contributing to the university's strategic goals of excellence, transformation, and sustainability.

CME's governance structure includes:

- **Management Committee, comprised of the following:**
  - Director (Chair)
  - Deputy Director(s)
  - Honours Programme Convenor
  - Principal Investigators of research groupings
  - Senior Technical Officer/Administrative Manager

  The responsibilities of the Management Committee include:
  - Develop and implement CME's strategic plan.
  - Oversee day-to-day operations and administration.
  - Ensure compliance with UCT policies and procedures.
  - Manage financial resources and budgeting.
  - Monitor and evaluate CME's performance.

- **Honours Programme Committee, comprised of the following:**
  - Honours Programme Convenor (Chair)
  - Course convenors of the Honours programme
  - Student representatives from the Honours cohort

  The responsibilities of the Honours Programme Committee
  - Develop and review the curriculum for the Honours programme.
  - Maintain high academic standards and foster innovation in the curriculum.
  - Ensure alignment of the Honours programme with CME's research focus and strategic goals.
  - Monitor the academic progress and welfare of Honours students.
  - Facilitate student involvement in research projects and industry partnerships.
  - Organise seminars, workshops, and other academic events for Honours students.

- Associate Academics (invited by the Management Committee) comprised of the following:
  - Associate Academics from relevant disciplines
  - Industry experts

  The responsibilities of the Associate Academics include:
  - Provide strategic guidance and advice.
  - Facilitate external collaborations and partnerships.
  - Facilitate financial support for CME and its research activities.
  - Contribute to teaching at undergraduate and postgraduate levels.
  - Support the pipeline for graduates to pursue higher degrees in materials engineering.

CME aims to review and evaluate its performance:
- Regularly review CME's activities and performance against its Aims and Strategic Objectives.
- Undergo external peer reviews as per UCT guidelines.
- Implement recommendations from reviews to ensure continuous improvement.

Amendments

- The Management Committee will review these Terms of Reference and amend them to reflect CME's Strategic Objectives and Governance changes.

APPENDICES

MSc(Eng) students

Student	Title	Supervisor
	2018	
Ferreira,Lizé-Mari	Green composites from castor oil and renewable reinforcing materials: maleated castor oil-polystyrene matrix reinforced with greige fibre	Chris Woolard
Matjee,Mapula Regina Kgabaeti	Investigation of the stress corrosion cracking resistance of SAF2205 and AISI304 weldments for the marine environment application	Robert Knutsen
Mayembo,Evrard Paterne	The influence of different chemical treatments on the mechanical properties of hemp fibre-filled polymer composites	Chris Woolard
Motibane,Londiwe Portia	A study on the effect of increased heat input on residual stress, microstructure evolution and mechanical properties in Ti6Al4V Selective Laser Melting	Robert Knutsen
Mutsakatira, Innocent Tapuwa	The effect of the surface condition of aluminium ingot (aa 3003) during roll bonding with the clad aluminium alloy aa4045 to form an aluminium brazing material	Sarah George
Nyakunu,Chenesai Nesisa	Mechanical property and meso-structure assessment of Ti6Al4V parts as function of high-speed selective laser melting practice (additive manufacturing): influence of laser scan rate on the microstructure and mechanical properties of SLM Ti6Al4V.	Robert Knutsen
Paul, Mikyle	The effect of the build orientation and heat treatment on the fatigue and fracture properties of a directed energy deposited nickel-based superalloy (Inconel 718)	Sarah George
Ramasimong,Duduzile	XRD Effectiveness in the Quantification of Fatigue Damage on AISI 316L Stainless Steel Material	Robert Knutsen
Stracey, Ibrahim	Development of a Small Punch Test rig for embrittlement testing of metallic materials.	Robert Knustsen
Dicks,James Anthony	Synthesis, Characterisation and Mechanical Properties of Polymeric Foams Derived from Castor Oil	Chris Woolard
	2019	
Lecheko,Relebohile Elliot	Microstructure - property relationships of power plant steels	Robert Knutsen
Maseti,Niyanda Sibulele	Thermomechanical processing of aluminium alloys	Sarah George

Ulassi,Anisha	Development of the level of uncertainty of NDT inspection techniques relating to boiler tubes with fly ash erosion degradation	Robert Knutsen

2020

Hlupo,Andrew	Validation and application of the small sample punch test for toughness measurement of steels	Robert Knutsen
Jambo,Tinashe Raphel	Influence of post-weld heat treatment (PWHT) on the tensile behaviour of P91 weldments	Robert Knutsen
Slater,Daniel George	Open-Source Software for Repeatable Processing of Mechanical Test Data	Ernesto Ismail/ Sarah George/ Ben Alheit

2021

Bampfield-Duggan,Jonathan Stuart	Machine learning-based identification of causes for inter-lot anisotropic variation in an AA5182 manufacturing line	Ernesto Ismail/Sarah George
De Jongh,Quintin Oliver	Design, Development and Testing of an Aerolap Polishing Machine for Selective Laser Sintered (SLS) Ti6Al4V Aerospace Components.	Ramesh/Sarah George
Maluleka,Patrick Tshepo	Quantification of the effects of thermal cycle on the intermetallic microstructure in 8000 series Aluminium alloys used in the battery foil applications	Sarah George
Senyolo,Morokolo Joel	Effect of Base Metal Oxygen Content and Oxygen Activity on Mechanical Properties of EN-GJL- GG - 26 CuCr Grey Cast Iron Heavy Duty Crank Cases	Robert Knutsen
Sibanyoni,Quinton	The influence of (Selective laser melting) SLM processing parameters on the microstructural and mechanical properties development of Beta 21S and TC11 titanium alloys.	Robert Knutsen
Thapelo Sibanyou	The effect of Build Orientation and Heat Treatment on Microstructure and Mechanical Properties of AlSi10Mg by Laser Powder Bed Fusion	Robert Knutsen

2022

Borrageiro,Roberto Antonio	Run out table creep of AA3104 CBS Material during hot rolling	Sarah George
Oosthuizen,Mary Katherine	Additive Manufacturing of High Strength Hardenable Aluminium Alloys	Thorsten Becker
Pitso,Limpho Patricia	The effect of Build Orientation and Heat Treatment on Microstructure and Mechanical Properties of AlSi10Mg by Laser Powder Bed Fusion	Thorsten Becker
Garschagen,Emma Nicola Annamarie	Development of testing apparatus, procedures, and a numerical model of annular shear testing of aluminium at industrially relevant elevated temperatures.	Ernesto Ismail/ Sarah George/ Ben Alheit
Vos,Maxwell Daymond	Development and implementation of an opensource DIC acquisition system, focusing on integration with the Gleeble 3800.	Sarah George

2023

Chaole,Nkopo Amelia	Investigating the effects of inter-pass time and strain per pass during hot finish rolling on the texture evolution of AA3104 CBS	Sarah George
Dallas,David John	Forming limit diagrams for AA5XXX aluminium alloys for automotive applications (MSc)	Sarah George
Lebakeng,Khethisa Eric	Correlation between homogenisation parameters and property evolution of AA3104 CBS after hot finish rolling	Sarah George
Maqina,Nonkosi Elizabeth	Development of titanium alloys for Additive Manufacturing	Thorsten Becker
Steyn,Willem Johannes Naudë	Development of biobased ionomers as self-healing materials.	James Dicks

2024

Harris,Samir	Extending A Digital Image Correlation algorithm to deal with discontinuous displacement and strain fields	Thorsten Becker
Nduna,Amandla	Disoersoids in AA3104	Sarah George
Ngatane,Bokang	Development of polymeric materials for additively manufactured biomedical phantoms for particle image velocimetry	James Dicks
Shiridzinomwa,Kelvin Kundai	Exploring the Impact of Additive Manufacturing Techniques on the Microstructural and Mechanical Properties of Ti-6Al-4V	Thorsten Becker
Tladi,Sepadi Jackson	Fatigue Properties Analysis of Ti6Al4V Samples Produced from Powder Blend of Titanium, Aluminum, and Vanadium	Thorsten Becker
Wichman,Dylan John	Near-threshold fatigue crack growth behaviour of AM ALSi10Mg	Thorsten Becker /Sarah George

PhD students

Student	Title	Supervisor

2019

Morrison,Graham Keith	Tensile Strength Anisotropy in AA5182 Aluminium Can End Stock: The Effect of Coil Coating on Microstructure	Sarah George
Mukwada,Lesley Lesley	Non-edible vegetable oil co-polymers prepared using renewable terpenoid monomers	Chris Woolard

2020

Allies,Soraya	Influence of primary process excursions on development of metallurgical variability and property degradation in x20 steel	Robert Knutsen

2021

Dicks,James Anthony	Investigating itaconic acid as a platform molecule for the functionalisation of biobased thermosetting polymers	Sarah George
Gholizadeh,Samira	An Investigation intoMicrostructural and Mechanical Properties Changes in Metallic Plates as a result of blast load	Steeve Chung Kim Yuen/ Sarah George

2022

Hills,Michael Andrew	Machine learning approach to predict the fatigue life of metal additively manufactured parts	Thorsten Becker
Motibane,Londiwe Portia	Producing ternary NiTiX alloys using Additive Manufacturing for biomedical applications	Thorsten Becker

2023

Rudolph,Sabrina Mary-Ann	Advancing Additive Manufacturing: A Machine Learning Approach to Predicting Titanium Alloy Material Properties	Thorsten Becker
Simelane,Khombisile Nondumiso	Additive Manufacturing of High Entropy Alloy for Potential in Hydrogen Storage Applications	Thorsten Becker

2024

Van Niekerk,Maryna Marne	Investigation of fatigue behaviour in Laser Powder Bed Fusion fabricated CoCrMo for biomedical implants.	Thorsten Becker

Post-Doctoral fellows

Name	Title	Supervisor
2022		
Alheit, Benjamin	Mathematical and computational modelling of aluminium forming	Sarah George
Kayode, Oyindamola	Microstructural factors affecting roll forces experienced during hot rough rolling of aluminium	Sarah George
2024		
Macallister,Nicolas	Defect population variability and fatigue life estimation of LPBF produced material	Thorsten Becker

Research outputs

Papers in peer-reviewed ISI journals

M Steytler and R Knutsen, Identifying Challenges to the Commercial Viability of Direct Powder Rolled Titanium: A Systematic Review and Market Analysis, Materials (2020) https://doi.org/10.3390/ma13092124

R Matthew, R Knutsen, J Westraardt and T Couvant , Adaptation of the point defect model to simulate oxidation kinetics of 316L stainless steel in the pressurised water reactor environment, Corrosion Science (2021) https://doi.org/10.1016/j.corsci.2021.109454

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J Gumede, B Hlangothi,C Woolard and S Hlangothi, Organic chemical devulcanization of rubber vulcanizates in supercritical carbon dioxide and associated less eco-unfriendly approaches: A review", Waste Management and Research (2021) http://dx.doi.org/10.1177/0734242X211008515

N Macallister and T Becker, Fatigue life estimation of additively manufactured Ti-6Al-4V: Sensitivity, scatter and defect description in Damage-tolerant models, Acta Materialia (2022 https://doi.org/10.1016/j.actamat.2022.118189

A Koko, E Elmukashfi, T Becker, P Karamched, A Wilkinson and T Marrow, In situ characterisation of the strain fields of intragranular slip bands in ferrite by high-resolution electron backscatter diffraction, Acta Materialia (2022) https://doi.org/10.1016/j.actamat.2022.118284

G Ter Haar G and T Becker, Laser powder bed fusion produced Ti-6Al-4V: Influence of high-energy process parameters on in-situ martensite decomposition and prior beta grain texture,Journal of Alloys and Compounds (2022) https://doi.org/10.1016/j.jallcom.2022.165497

I Vazirgiantzikis and S George, Surface characterisation and silver release from Ti-6Al-4V and anodic Ti02 after surface modification by ion implantation, Surface and Coatings Technology (2022) https://doi.org/10.1016/j.surfcoat.2022.128115

S von Willingh and R Knutsen, Effect of prior austenitisation temperature on creep rupture in Grade 22 steel, Materials at High Temperatures (2022) https://doi.org/10.1080/09603409.2022.2058227

V Vilane, R Knutsen and j Westraadt, Tensile property and microstructure assessment of hydrogen treated Ti-6Al-4V alloy, Materials Characterization (2022) https://doi.org/10.1016/j.matchar.2021.111698

G Leteba, D Mitchell, L Macheli, P Leveque, E van Steen and C Lang , Catalytic Properties of Molybdenum-Modified Platinum Nanoalloys toward Hydrogen Evolution, Oxygen Reduction Reaction, and Methanol Oxidation, ACS Applied Energy Materials (2022) https://doi.org/10.1021/acsaem.2c02771

L Cremer, B Nortje, J van der Merwe and T Becker, Wear of Conventional UHMWPE Articulating Against Additively Manufactured Ti-6Al-4V and Co-Cr-Mo , Biotribology (20223) https://doi.org/10.1016/j.biotri.2022.100231

A Koko, T Becker, E Elmukashfi, N Pugno, A Wilkinson and T Marrow T, HR-EBSD analysis of in situ stable crack growth at the micron scale, Journal of the Mechanics and Physics of Solids (2023) https://doi.org/10.1016/j.jmps.2022.105173

D Gibbons, W Makhetha, T Becker and A van der Merwe, Characterisation of the Tensile and Metallurgical Properties of Laser Powder Bed Fusion-Produced Ti-6Al-4V ELI in the Duplex Annealed and Dry Electropolished Conditions, Metals (MDPI) (2023) https://doi.org/10.3390/met13081390

N Macallister, S Chellu, T Riemslag, S Scott, C Ayas, V Popovich and T Becker, Sub-size specimen testing for near-threshold fatigue crack behaviour of additively manufactured Ti-6Al-4V, Materialia (2023) https://doi.org/10.1016/j.mtla.2023.101852

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S George and L Chicuba, Intermetallic and dispersoid structures in AA3104 aluminium alloy during two-step homogenisation, Nature Research (2024) https://doi.org/10.1038/s41598-024-51890-2

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L Macheli, G Leteba, B Doyle, L Jewell and E van Steen, Modulating CO hydrogenation activity through silane functionalization of cobalt catalysts, Applied Catalysis A (2024) https://doi.org/10.1016/j.apcata.2024.119874

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A Daliri, A Orifici, R Curry, G Langdon, H Bornstein and R Odish, Experimental response of S2-glass fibre reinforced composites subjected to localised blast loading, 7th International Conference on Structural Engineering, Mechanics & Computation, Cape Town, September 2-4, 2019 https://doi.org/10.1201/9780429426506-142

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M Van Rooyen and T Becker, An Experimental Approach to the Application of Digital Image Correlation to Small Punch Creep Testing, South African Conference on Computational and Applied Mechanics, Cape Town, South Africa (2021)

M Blackwell, M van Rooyen and T Becker, A numerical approach for designing functionally stiff triply-periodic-minimal-surface structures, MATEC WEB OF CONFERENCES: 2022 RAPDASA-RobMech-PRASA-CoSAAMI Conference
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