CENTRE FOR HIGH RESOLUTION TRANSMISSION ELECTRON MICROSCOPY

2011-2015

FOREWORD

Prof JH Neethling
Director: Centre for HRTEM

The Centre for High Resolution Transmission Electron Microscopy was officially launched on the 11th October 2011 and is now in it's fourth year of operation. This report gives an overview of the progress and activities of the Centre to date. The last four years have been exciting times with publications in international journals, successful new local and international collaborations, and widespread recognition for the high quality and relevance of the research carried out at the Centre for HRTEM.

The Centre is also very proud of the progress that has been made in the training of emerging scientists in materials characterisation using advanced electron microscopy techniques; and the significant number of postgraduate students from other institutions that have been assisted with their research projects.

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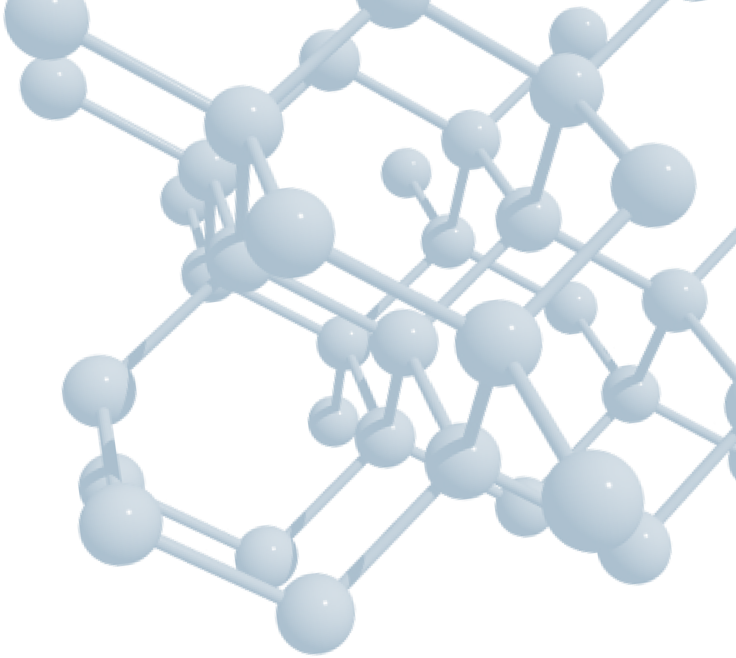
CONTENTS

A BUILDING ENVIRONMENT TO ACHIEVE ATOMIC RESOLUTION: The Centre building took two years to design (2008-2009) and was influenced by a number of electron microscope site designs and site visits to Europe. Special consideration needed to be given to ensure that the building would meet the required specifications to allow the HRTEM microscope to work at maximum proficiency. This included taking into consideration mechanical and acoustic vibrations, air pressure pulses, magnetic fields, stable electrical supply, air flow, air temperature, humidity and stable cooling water. The tender and building process commenced in 2010 and the practical completion of the building was in April 2011.

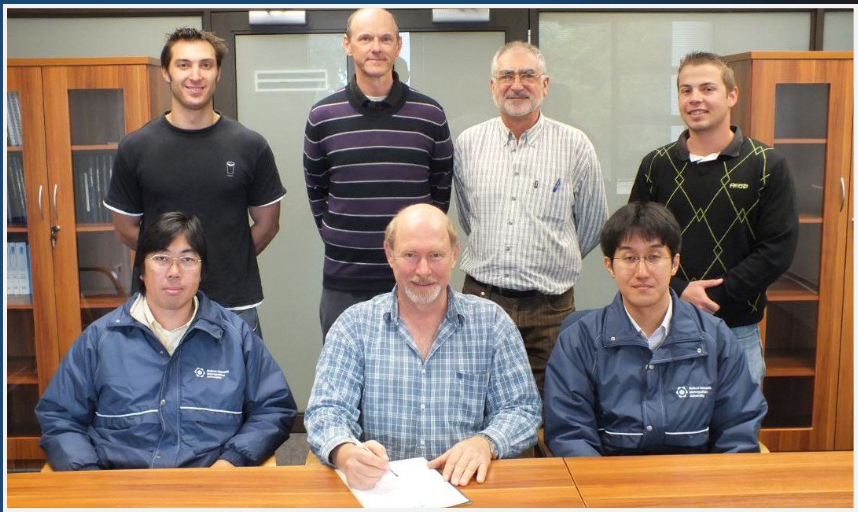
Sod-turning ceremony: (Left) Director of the Centre for HRTEM (Prof Jannie Neethling) (Right) Vice-chancellor of the NMMU (Prof Derrick Swartz).



Background

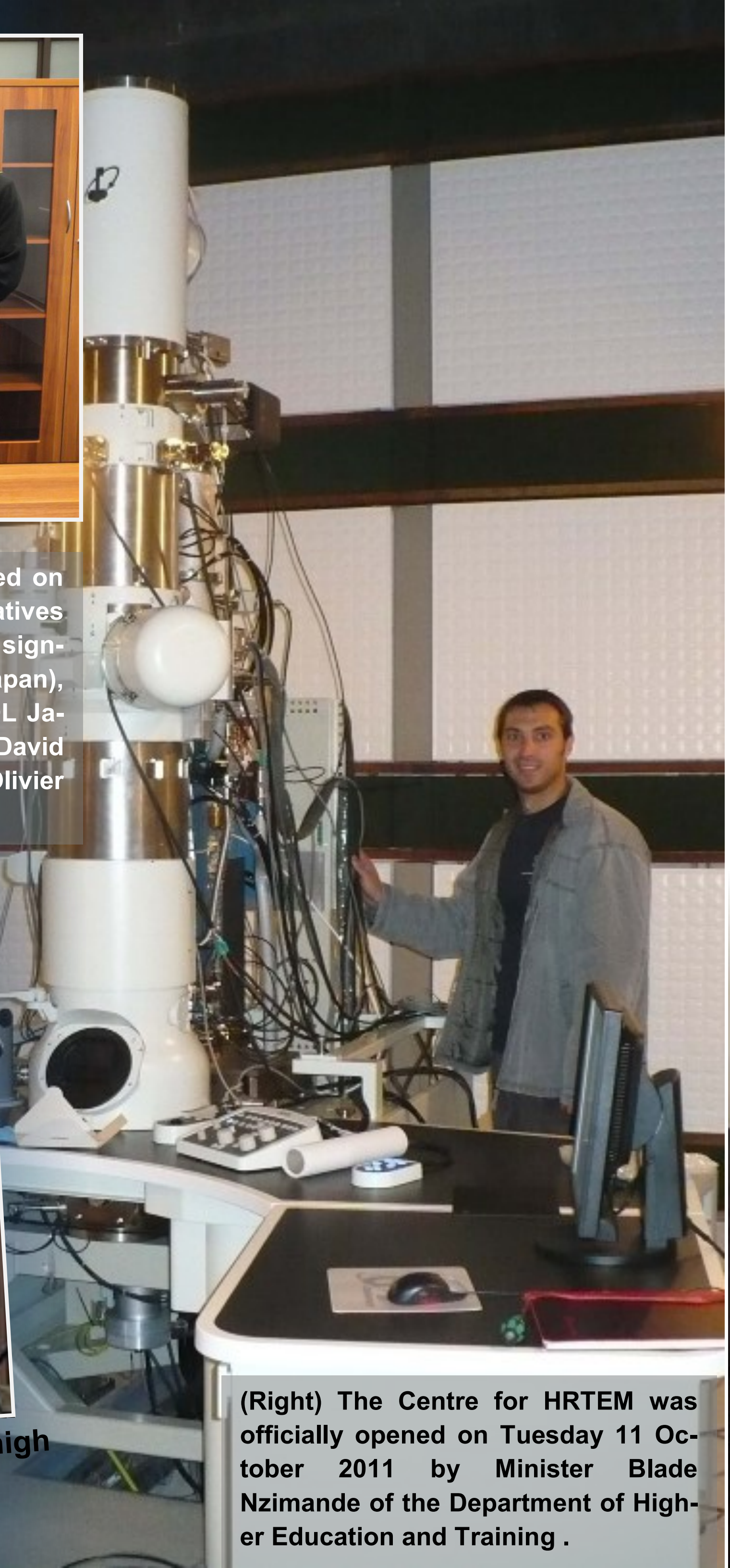
In 1983 a committee of prominent SA scientists investigated the need for an advanced electron microscopy facility for SA. It was concluded that, unless the problem of the lack of a modern HRTEM and skilled microscopists were rectified, technological and academic developments in South Africa would be significantly hampered. Almost three decades later, on 11 October 2011, the first Centre for High Resolution Transmission Electron Microscopy (HRTEM) was launched at NMMU.

A key initiative of the National Nanotechnology Strategy approved by Cabinet is to "*create the physical infrastructure to enable first-class basic research, exploration of applications, development of new industries, and commercialization of innovations*." Without the Centre for HRTEM at the NMMU, nanomaterials, which are of fundamental as well as strategic industrial importance, cannot be adequately researched and developed in South Africa.



The final acceptance of the JEOL ARM HRTEM was signed on 17 November 2011. The above image shows the representatives from the Centre for HRTEM, JEOL Japan and Sasol at the signing ceremony. Front, from left: Dr Eiji Okunishi (JEOL Japan), Prof Jan Neethling (CHRTEM), Dr Kazuya Tsunehara (JEOL Japan). Back, from left: Mr Jacques O'Connell (CHRTEM), Dr David Mitchell (Sasol), Prof Mike Lee (CHRTEM), Dr Jaco Olivier (CHRTEM).

Procurement, delivery and installation of the high resolution transmission electron microscope.



(Right) The Centre for HRTEM was officially opened on Tuesday 11 October 2011 by Minister Blade Nzimande of the Department of Higher Education and Training .

"It has catapulted NMMU to the forefront of global nano-science research and will provide South Africa with cutting-edge capability in national priorities like clean water, energy, minerals' beneficiation and manufacturing."

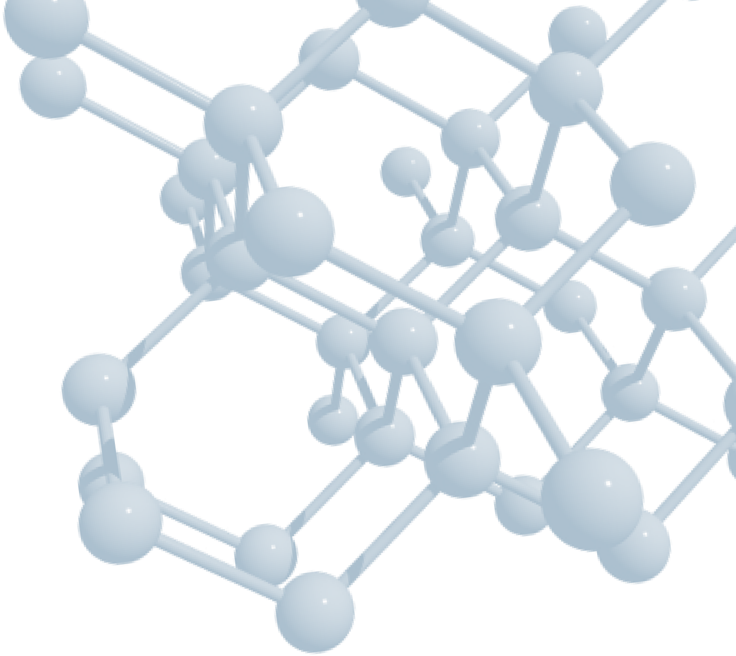
Minister Blade Nzimande
Department of Higher Education and Training

Vision

To be a leading advanced electron microscopy centre for research and training.

Mission

To provide a broad community of SA scientists and students with a full range of state-of-the-art instruments needed for nanoscale materials research and to provide expert support and solutions to a wide range of materials research questions.



Vision and mission

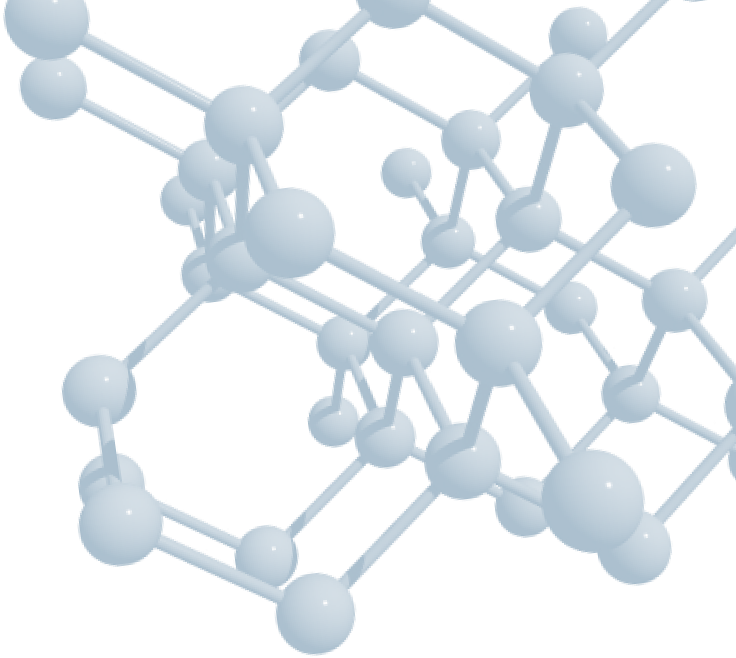
The Centre for High Resolution Transmission Electron Microscopy is a facility for advanced electron microscopy situated at the Nelson Mandela Metropolitan University in Port Elizabeth, South Africa. The main aim of the Centre for HRTEM is to provide a broad community of South African scientists and students with a full range of state-of-the-art instruments and expertise for materials research.

JEOL ARM200F DOUBLE CS CORRECTED TEM

The JEM-ARM200F is a double corrected Atomic Resolution Analytical Electron Microscope. Imaging modes include high-resolution TEM (110 pm) and STEM (78 pm). These exceptional spatial resolutions are achieved through additional lenses that correct for the spherical aberration.

Analytical attachments include a large solid angle energy dispersive spectrometer (EDS) and a duel electron energy loss spectrometer (EELS). The aberration corrected electron STEM probe has a current density that is an order of magnitude higher than conventional field emission instruments. This allows for imaging and fast chemical mapping down to the atomic level.

The JEM-ARM200F is housed in a purpose-built room that limits environmental variations (vibration, thermal, moisture and electrical interference). This is an absolute necessity for the instrument to perform at ultra-high resolution.



Facilities

The Centre for HRTEM houses four state-of-the-art electron microscopes including the only double aberration corrected transmission electron microscope on the African continent. Other instruments include a fully analytical TEM, a focused ion beam scanning electron microscope, an analytical high resolution SEM, a nanoindentor and an atomic force microscope. The Centre also houses the enabling infrastructure for sample preparation and data processing.

Visit our website (chrtem.nmmu.ac.za) for more details on available facilities and services.

FEI HELIOS NANOLAB 650 FIB-SEM

The Helios NanoLab DualBeam 650 is a Scanning Electron Microscope (SEM) / Focused Ion Beam (FIB) workstation capable of advanced nano-analysis and sample preparation.

For site-specific TEM specimens, the FIB-SEM is routinely used to produce electron transparent membranes with the use of focused gallium ion beams.

In addition, the Helios Nanolab 650 FIB-SEM boasts a wide variety of detectors capable of excellent SEM imaging quality. The system architecture is optimised for automation, and features include Auto FIB, Auto TEM, and Auto Slice and View.

JEOL 2100 LAB6 TEM

The JEM-2100 (LaB6) is a multipurpose, analytical electron microscope, and supports research and development in both biological and materials sciences. Imaging modes include high-resolution TEM (230 pm) and scanning transmission electron microscopy (STEM). Analytical attachments include an energy dispersive spectrometer (EDS) and an electron energy loss spectrometer (EELS). These attachments used in combination with the STEM allows for imaging and chemical analysis down to the nanometer scale.

The JEM-2100 is housed in a purpose-built room that limits environmental variations (vibration, thermal, moisture and electrical interference).

JEOL 7001F ANALYTICAL FEG SEM

The JEOL 7001F is an easy-to-use Schottky type FEG SEM. In addition to a secondary electron (SE) detector and a retractable back-scattered electron (BSE) detector, the SEM is also equipped with a number of analytical detectors including an energy dispersive spectrometer (EDS), a wavelength dispersive spectrometer (WDS) and an electron backscatter detector (EBSD), which makes it a versatile analytical tool.

SAMPLE PREPARATION

The Centre houses the necessary equipment to prepare specimens for both materials and biological research. Specimens are prepared with assistance from a dedicated sample preparation team. Facilities and techniques include diamond wire saws, a diamond disc saw, cold mounting, a hot mounting press, grinding and polishing machines, a suite of Gatan PIPS ion mills, and an ion-cross polisher. For SEM analysis of electrically nonconductive materials, there are two sputter coaters for gold, iridium or carbon coating. The Centre also have an ultramicrotome and critical point dryer for the preparation of biological samples.

NANOINDENTER AND ATOMIC FORCE MICROSCOPE

The nanoindenter tests selective mechanical properties such as hardness and elasticity of materials on the nanometer to micrometer scale using a Berkovich type tip.

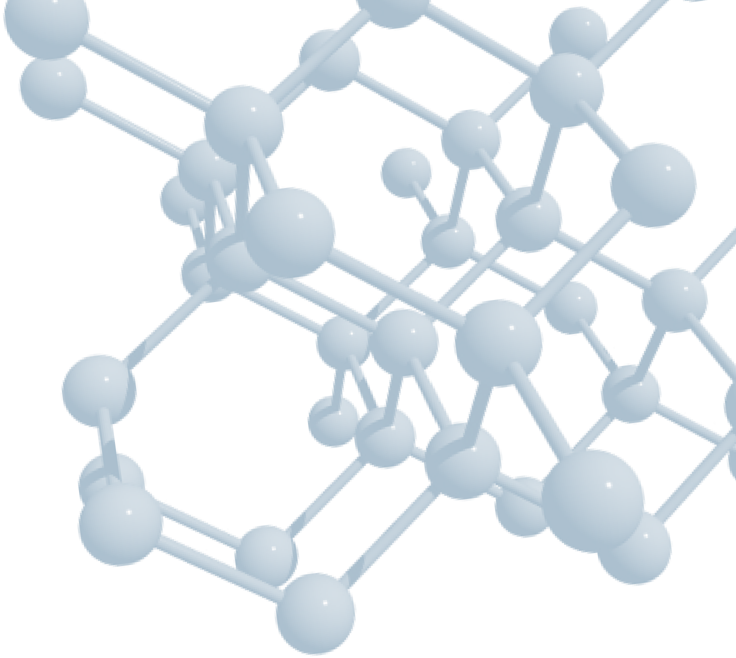
The nanoindenter is equipped with an atomic force microscope (AFM) which is used to image the surface of materials on an atomic scale. It is used for high resolution topographic analysis, and provides a three-dimensional surface profile of a sample. The recorded data can be displayed using image processing software as brightness values or colour values for each pixel.

MATERIALS MODELING AND SIMULATION

The Centre for HRTEM actively focuses on increasing capacity in software utilization to process experimental data. A list of simulation/modeling software packages available at the Centre follows:

- JEMS: Software package for the simulation of HRTEM images, diffraction patterns and various other electron beam-specimen interactions.
- ICSD: The inorganic crystal structure database with more than 161 000 crystal structures. Copyright – FIZ Karlsruhe.
- Aztec: Used for EBSD / EDS analysis.
- Gatan digital micrograph: record, edit and analyse TEM images.
- GPA: Software for Geometric Phase Analysis. GPA generates fully quantitative deformation and strain maps from HR(S)TEM images.
- Channel 5 HKL: Used for EBSD analysis.
- Amira: 3D reconstruction of FIB sections.
- IGOR pro 6.3: Powerful scientific graphing, data analysis, image processing and programming software tool for scientists and engineers. It is used to model EELS edges.
- CRISP: Image processing of HRTEM images (Calidris).
- Image-J
- muSTEM: HR STEM image simulation program
- MatCalc: Software for computer simulation of phase transformations in metallic systems.

Ms Velile Vilane (right) receiving TEM training from Dr Johan Westraadt (left). Ms Vilile Vilane – a PhD student from the Centre for Materials Engineering at UCT – is receiving extensive training in electron microscopy as part of a special TEM training intervention of the Centre for HRTEM. This training forms part of her PhD studies on titanium alloys, of which the beneficiation is a strategic initiative supported by the DST. Ms Vilane is the first external student to receive this degree of comprehensive training and the aim is to develop her into a competent TEM scientist and skilled user. This model of training is proving successful, and can be used to develop microscopists from other institutions if they can spend sufficient time at the Centre for HRTEM.



Services

The core services provided by the Centre for HRTEM include:

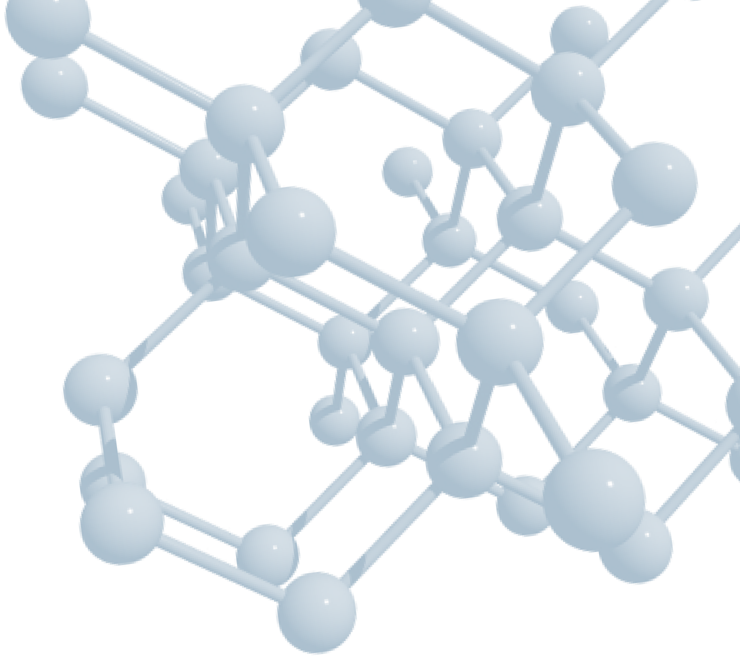
Postgraduate and postdoctoral support and training: Postgraduate and postdoctoral positions are available at the Centre for HRTEM. Prospective students are advised to visit our website for more information on possible research fields and study opportunities. The Centre also provides advanced microscopy support and training to postgraduate students and researchers from a wide range of disciplines who do not have similar facilities at their host institutions. Details on the application process can be found on our website.

Operator training: In addition to training postgraduate students, the Centre also provides training to microscope operators at electron microscope facilities across the country.

Consultancy: The Centre provides consultancy and microscopy services to industry, R&D institutions and academic institutions.

Sample preparation: The Centre provides sample preparation services in instances where the requested techniques are not available at the host institution.


Management Committee
Advisory Board
Management and Operations Team
User Forum
Proposal Screening Committee

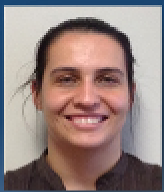


Governance and management structure

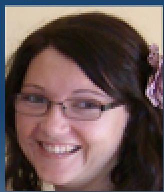
The Centre for HRTEM is an official research entity within NMMU's Faculty of Science. There are various committees overseeing the running of the Centre. The Centre's ***management and operations team*** is made up of Centre staff members and focuses on the day-to-day operations and management of the Centre. In addition, the Centre is governed by a ***management committee*** comprised of NMMU staff members representing the Centre, the department of research management, the department of finance, and various academic departments from the faculties of science and engineering that make use of the Centre. The committee meets quarterly, and is responsible for the effective running of the Centre, approval of finances and ensuring performance against set objectives. The ***advisory board*** consists of representatives from the Centre, NMMU management, industry, government (the DST and the NRF), users and international and local experts who meet biannually to review the management, utilisation and outputs of the Centre. An external ***proposal screening committee*** composed of South African experts review and make recommendations on applications received for the use of the HRTEM and feeder TEM. A ***user forum*** representing current and potential users meet annually at the Microscopy Society of Southern Africa Conference to discuss current and future research services and support required from the Centre.

DIRECTOR
Prof JH Neethling

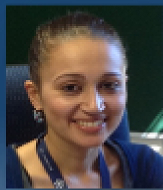
MANAGER
Prof ME Lee



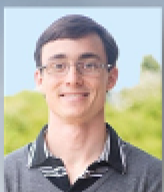
ADMIN/FINANCE OFFICER
Ms M Kolver



PROJECT COORDINATOR
Ms L Westraadt

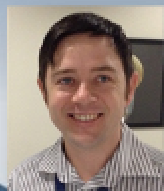


MSc NANOSCIENCE NODE ADMIN
Ms N Agherdien



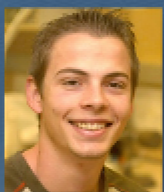
FEEDER TEM SCIENTIST
Mr A Janse van Vuuren

FIB-SEM SCIENTIST
Mr E Minnaar



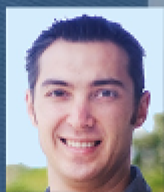
SENIOR RESEARCH FELLOW
Dr JE Westraadt

HRTEM/TEM SPECIMEN ASSISTANT
Mr N Mfuma

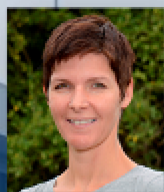


HRTEM SCIENTIST
Dr JE Olivier

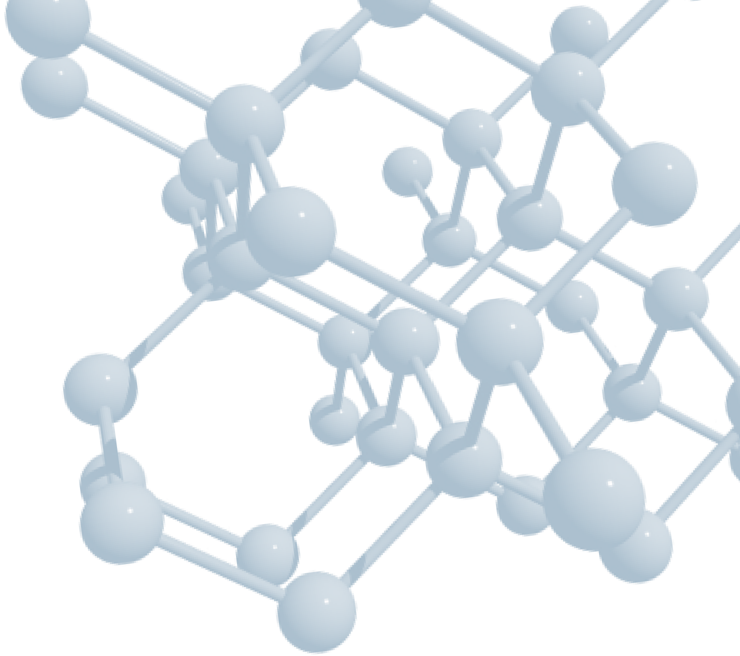
FEG SEM SCIENTIST
Mr WE Goosen



MICROSCOPE ENGINEER
Dr JH O'Connell



TEM/SEM SPECIMEN ASSISTANT
Ms C Blom

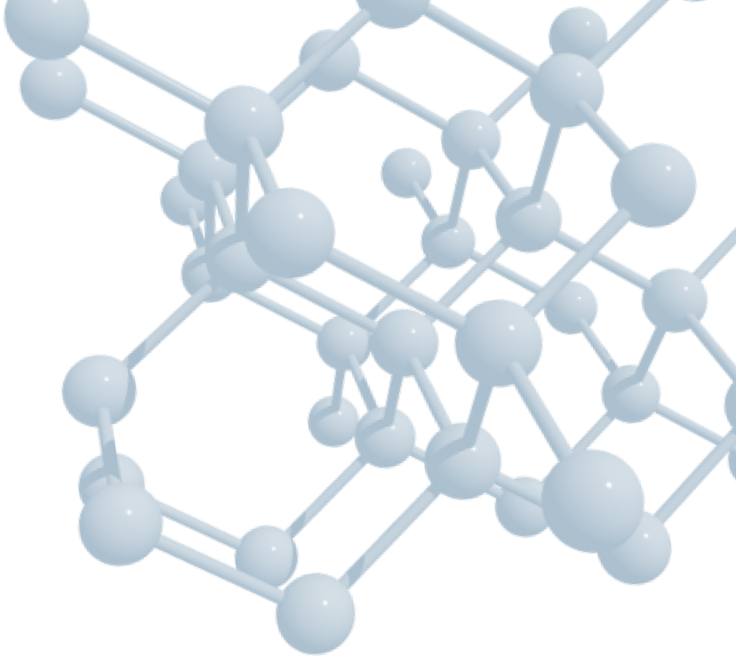


Staff

A world-class team for a world-class facility.

RESEARCH THAT MAKES A DIFFERENCE: The ultimate goal of research at the Centre for HRTEM is to support the sustainable development of the South African economy while aiming for international competitiveness. Focus areas include:

- **Materials modeling and HRTEM techniques and simulation;**
- **Energy materials – coal and nuclear power plants;**
- **Nanoparticle catalysts;**
- **Minerals beneficiation; and**
- **Biological and biomedical microscopy.**



Research and collaborations

Research at the Centre is multi-disciplinary and focuses on the application of high resolution and analytical electron microscopy techniques in the characterisation of strategic materials. The ultimate goal is to support the sustainable development of the South African economy while aiming for international competitiveness. Collaborators include local and international leaders in physics, chemistry, biological sciences, materials science, geology and mechanical and nuclear engineering.

HRTEM TECHNIQUES

COLLABORATORS

- Oxford University, UK
- University of Melbourne, Australia
- Stuttgart Center for Electron Microscopy, Max Planck Institute for Intelligent Systems, Germany

It is essential that scientists at the Centre for HRTEM remain current with international trends and standards in electron microscopy. To this end, the Centre maintains close collaborations with international leaders in the field. International collaborations include:

- collaboration with the Department of Materials at Oxford University in the UK (Prof A Kirkland) on advanced high resolution techniques such as “exit wave reconstruction” and HRSTEM of graphene;
- collaboration with Prof Les Allen from the University of Melbourne in Australia on the use of dedicated HRSTEM image simulation software; and
- collaboration with Prof Peter van Aken from the Stuttgart Center for Electron Microscopy at the Max Planck Institute for Intelligent Systems on the use of high resolution EELS and next generation EDS.

HONORARY PROFESSOR
Prof Peter van Aken
Stuttgart Center for Electron Microscopy
Max Planck Institute for Intelligent Systems

HONORARY PROFESSOR
Prof Angus Kirkland
Department of Materials
Oxford University

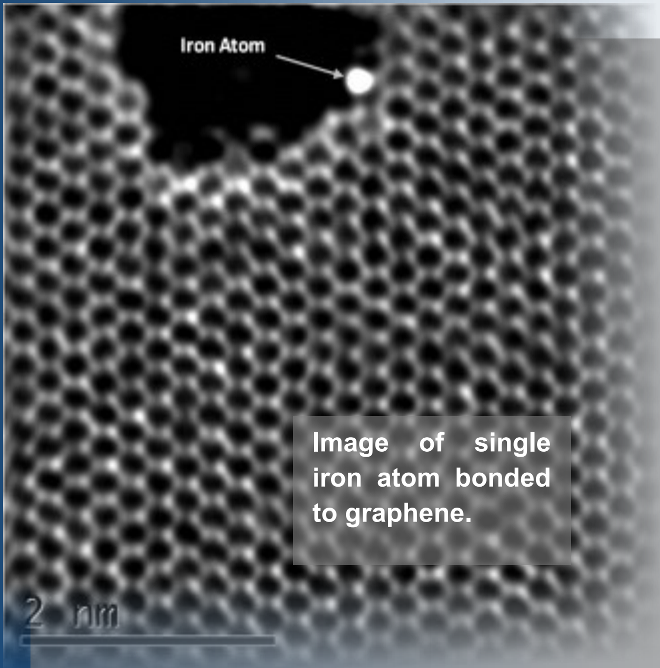


Image of single iron atom bonded to graphene.

On Friday 1st of June 2012, Dr Jamie Warner from the Department of Materials at Oxford University, shared the exciting news with Herald reporters that the new JEOL high resolution transmission electron microscope (HRTEM) at the NMMU had successfully produced very good images of single iron atoms in graphene. Graphene, which was discovered in 2004, consists of a single layer of carbon atoms packed in a honeycomb structure. Since it is stronger than steel and conducts electricity as well as copper, it has promising applications in future high-speed electronic devices. There are only a handful of research groups in the world who are able to perform this experiment.

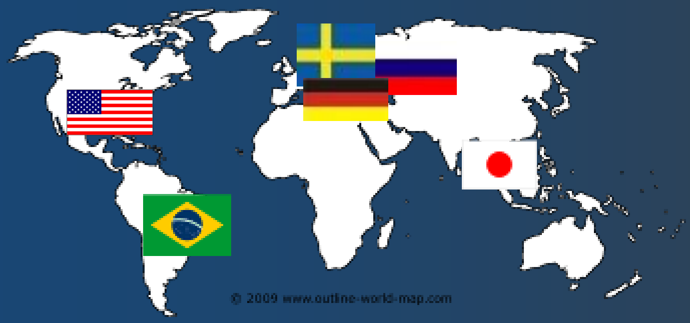
Dr Warner remarked that the following four requirements must be satisfied in order to obtain these cutting-edge results: A good specimen, a very good atomic resolution electron microscope, a highly skilled electron microscope operator (Dr Jaco Olivier) and a well-designed and stable building such as the Centre for HRTEM at NMMU. This achievement proves that the Centre for HRTEM at NMMU has the equipment and expertise to participate in cutting-edge research programmes with top international scientists.

During the invited talk presented by Dr Jamie Warner from Oxford University at the 2012 European Microscopy Congress, he showed the HRTEM image of graphene and EELS results obtained at NMMU and he acknowledged the Centre for HRTEM. This work has now been published in Nature Communications.

OXFORD CONNECTION: Dr Jamie Warner (front), and his wife Frewyeni Kidane, both of Oxford University, look at images of the potentially revolutionary nano-material, graphene, isolated by the new state-of-the-art microscope at NMMU. Seated next to Warner is NMMU's Dr Jaco Olivier with collegue, Professor Jan Neethling, standing behind him Picture: BRIAN WITBOOI

The Herald, Thursday June 7, 2012.

NUCLEAR REACTOR MATERIALS



COLLABORATORS

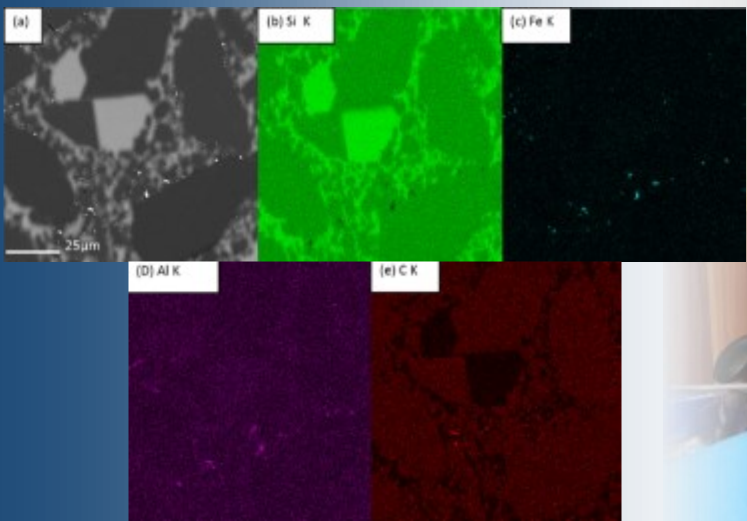
- Joint Institute for Nuclear Research (JINR), Dubna, Russia
- University of Linköping, Sweden
- Idaho National Laboratory (INL), USA
- Technical University, Dresden, Germany
- GSI Helmholtz Centre for Heavy Ion Research, Germany
- Westinghouse Electric Company, US and Sweden
- University of São Paulo, Brazil
- Institute for Advanced Energy, Kyoto University, Japan

The Centre is investigating the effects of swift heavy ion impact on Oxide Dispersion Strengthened (ODS) steel alloys, zirconium nitride (ZrN) and zirconium titanium nitride (ZrTiN) as part of a collaboration with the Joint Institute for Nuclear Research (JINR), Dubna, Russia. ODS steel is a very promising nuclear reactor fuel cladding material because of its high swelling resistance and high temperature strength. ZrN is another promising ceramic that is being considered for an inert matrix fuel host for fast reactors and ZrTiN has potential as accident tolerant coating on zircaloy. The collaboration on ODS steel now also includes the Institute for Advanced Energy, Kyoto University, Japan.

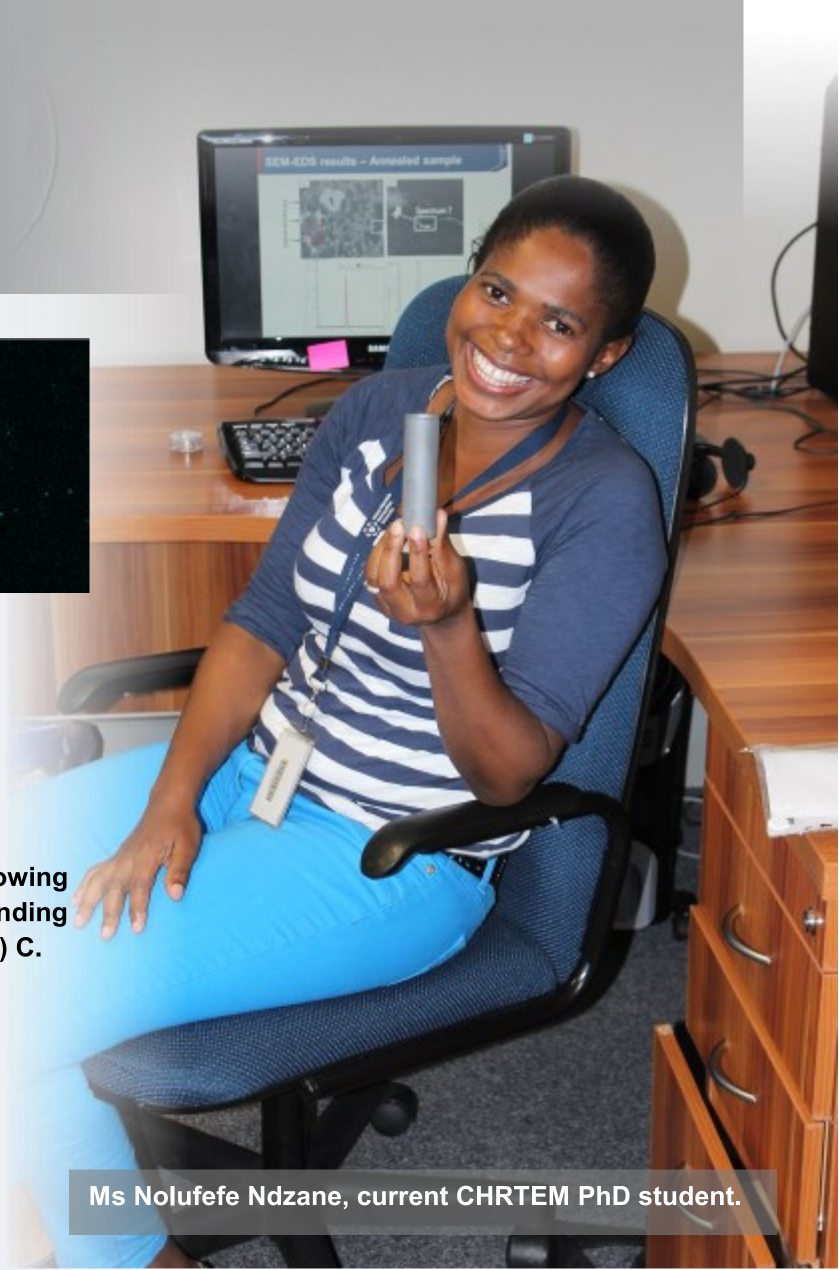
Other collaborations focusing on nuclear reactor materials include:

- research in collaboration with the University of Linköping in Sweden on the nuclear reactor ceramics, ZrN and ZrC, prepared in Sweden;
- collaboration with the Idaho National Laboratory (INL) on the investigation of fission product transport in TRISO coated nuclear reactor fuel particles;
- collaboration with the Technical University in Dresden on the laser joining of SiC containers for the immobilization and storage of nuclear waste;
- heavy ion co-implantation in SiC will be carried out at the GSI Helmholtzzentrum, Darmstadt, Germany to enable the Centre to investigate co-diffusion of metallic fission products in SiC;
- research on the new accident tolerant fuel coatings on zircaloy fuel tubes for water cooled (PWR) nuclear reactors in collaboration with Westinghouse and other international institutions; and
- collaboration with the University of São Paulo in Brazil on the use of nanoparticles for the removal of radionuclides from wastewater.

The Centre is involved in a number of nuclear reactor materials research projects which are focused on the development of advanced zirconium-alloy and ceramic fuel claddings for water cooled nuclear reactors. The new advanced fuel claddings are designed to reduce the oxidation rate of the cladding and hydrogen generation during both normal and high temperature accident conditions. Silicon carbide (SiC) is being investigated as a new type of cladding and for the immobilisation of radioactive nuclear waste. Ms Nolufefe Ndzane (below, right), as part of her MSc study, investigated the microstructure and fission product retention properties of SiC tubes manufactured by using the reaction bonding process. Typical results obtained are shown below. A scanning electron microscope image of the reaction bonded silicon carbide is shown (a) with elemental maps for silicon, iron, aluminium and carbon shown in (b) to (e), respectively.



(a) BSE SEM image of the RBSiC sample showing atomic number related contrast and corresponding EDS elemental maps for (b) Si, (c) Fe, (d) Al and (e) C.



Ms Nolufefe Ndzane, current CHRTEM PhD student.

COAL-FIRED POWER PLANT STEELS

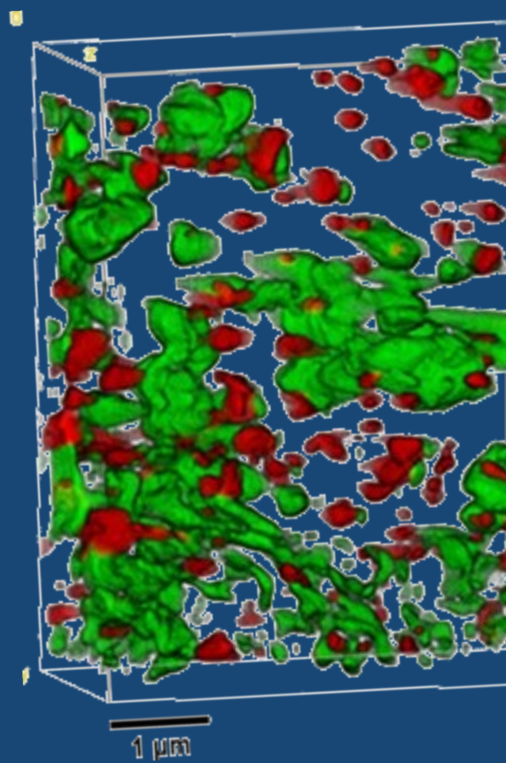
COLLABORATORS

- Centre for Materials Engineering (CME), UCT
- Eskom
- eNtsa, Mechanical Engineering, NMMU

As part of the Eskom programme to promote research activity and develop human resources, the Eskom Power Plant Engineering Institute (EPPEI) Materials Science Specialization group was established at the CME at the University of Cape Town at the beginning of 2012. The CME then entered into a collaboration agreement with the Centre for HRTEM to participate in the Eskom Materials Science Specialisation programme in order to derive substantial support in advanced materials characterization of power plant materials using high resolution electron microscopy. The aim of this collaboration is to promote research excellence in areas that will support the power generation industry and the focus is on the high temperature behaviour of engineering materials with emphasis on materials that are exposed to high temperature and high stress conditions in coal fired power plants.

Current research projects focus on the structure-to-properties relationships of power plant steels with specific interest in stress corrosion cracking—both in the coal and nuclear environments; and in refining the weldability limits of creep-aged coal-fired power plant steels. Current remaining-life assessment models in use by Eskom are conservative, and further knowledge will allow for more efficient replacement of expensive components. It is important to replace components before creep damage deteriorates the material to the point where failure is inevitable, but also not too early otherwise money will be wasted.

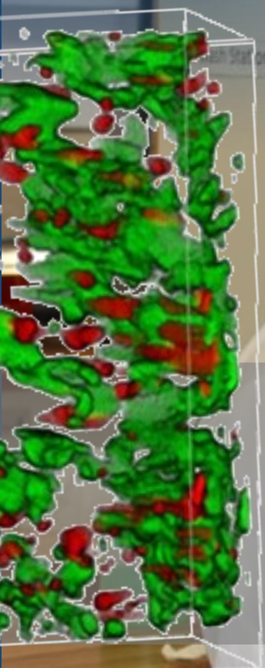
Related research is also carried out together with eNtsa—part of the Mechanical Engineering department at NMMU. eNsta developed the friction stir hydropillar process used by ESKOM to sample aging power-plant steel for lifetime analyses. The Centre is assisting eNsta with the study of the microstructural effects of this process.



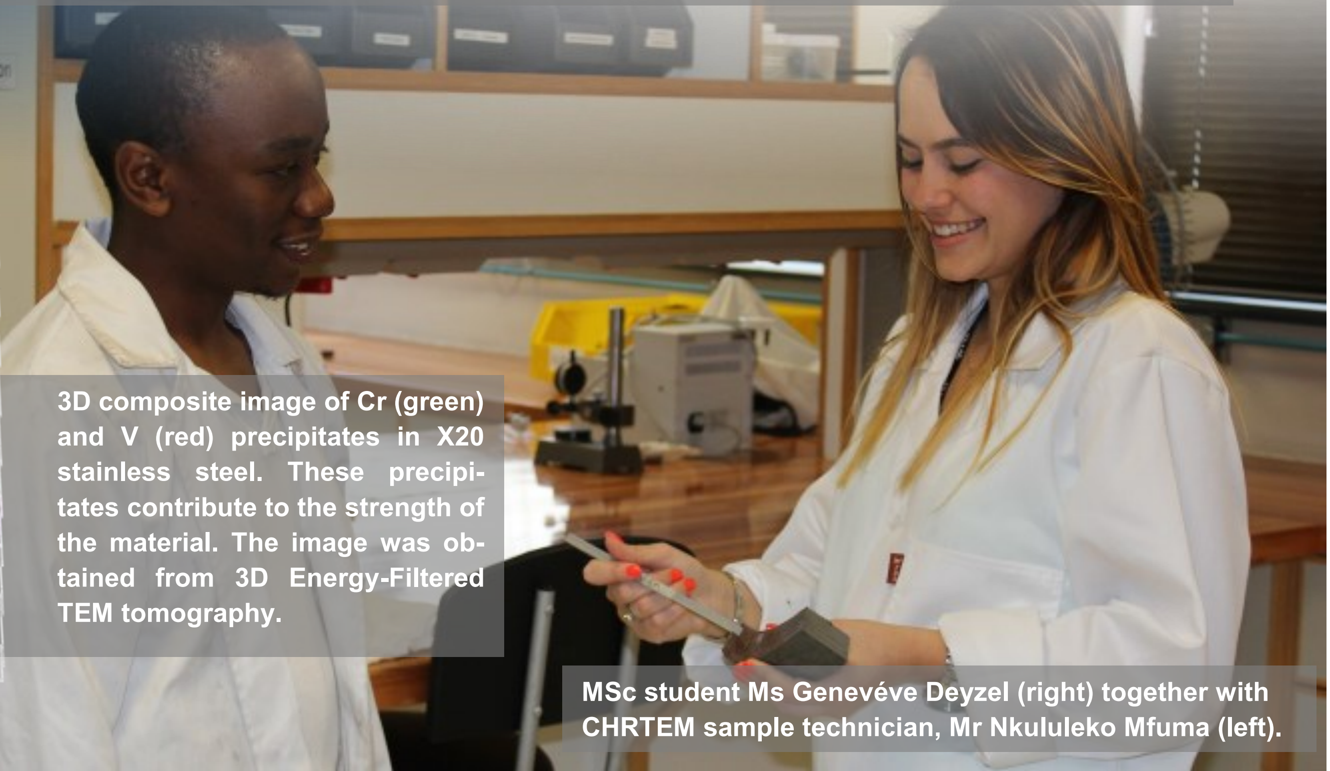
RESEARCH FEATURE

Dr Westraadt on site at the ESKOM Kriel power station.

MSc student, Ms Genevéve Deyzel, is using advanced microscopy to refine Eskom's remaining-life assessment models. X20 (12% Cr) stainless steel is used for the main steam pipes at Eskom's coal fired power plants. These components are susceptible to creep damage, and need to be replaced at the end of their working life. To replace aged material, new steel components are joined to existing components using manual metal arc welding. The weldability of material decreases with creep ageing and a limit is reached where welding cannot be permitted on the aged material. It is therefore very important to replace the component before creep damage deteriorates the material to the point where failure is inevitable, but also not too early otherwise money will be wasted. The main aim of Genevéve's project is to characterise the microstructure of creep aged 12Cr steels so that it is possible to make recommendations towards more realistic weldability limits for these steels to prevent permanent failure of the whole component. This is being achieved by using advanced electron microscopy to develop, critically evaluate and apply microstructural measuring techniques to creep resistant X20 weldments.



3D composite image of Cr (green) and V (red) precipitates in X20 stainless steel. These precipitates contribute to the strength of the material. The image was obtained from 3D Energy-Filtered TEM tomography.



MSc student Ms Genevéve Deyzel (right) together with CHRTEM sample technician, Mr Nkululeko Mfuma (left).

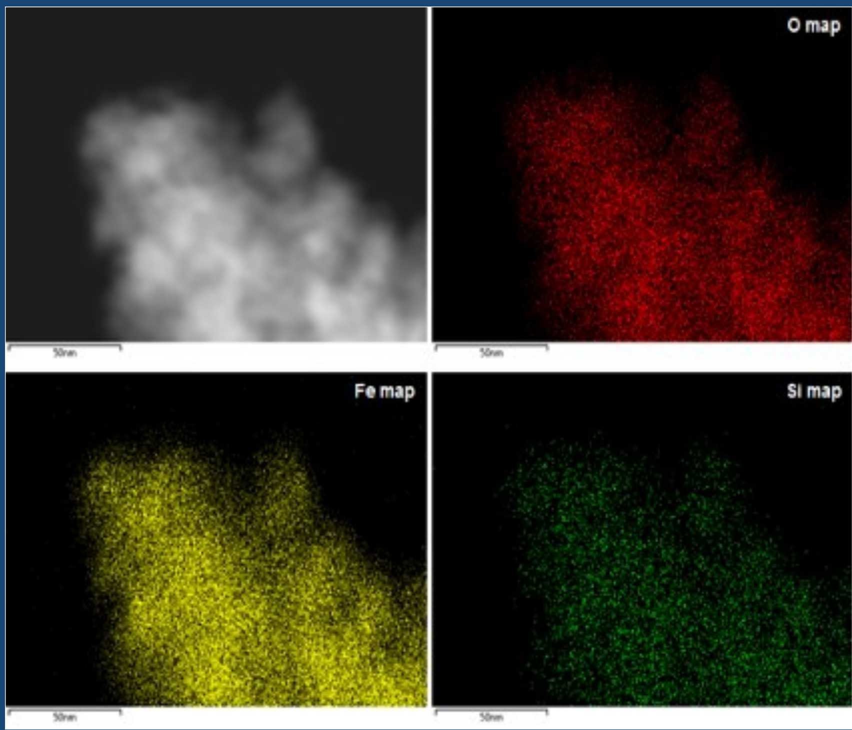
NANOPARTICLE CATALYSTS

COLLABORATORS

- Sasol
- DST-NRF Centre of Excellence in Catalysis, Department of Chemical Engineering, UCT
- Universität Osnabrück, Germany
- Oxford University, UK
- University of New Mexico, USA

The core business of Sasol is the conversion of syngas (derived from coal or natural gas) into a range of energy and chemical products, including transport fuels, base oils, waxes, paraffins and naphtha. The catalytic properties of a catalyst are influenced by its composition and structure at the atomic scale. Postgraduate researchers at the Centre for HRTEM assist Sasol in improving their understanding of the crystal structure and catalytic activity of Fischer-Tropsch catalysis by applying advanced electron microscopy. To study catalysts at the atomic scale requires the use of an aberration corrected high resolution transmission electron microscope (HRTEM) and these investigations can only be performed at the Centre for HRTEM at NMMU as it houses the only Cs- corrected HRTEM in Africa.

Other collaborators in the field of nanoparticle catalyst research include scientists from Oxford University (Prof A Kirkland), the University of New Mexico (Prof A Datye) in the US, and Dr Karsten Küpper, Universität Osnabrück, Germany. The collaboration with Dr Küpper focuses on HRTEM, HRSTEM and EELS analysis of core shell nanoparticles. The Centre now also collaborates with the DST-NRF Centre of Excellence in Catalysis, Department of Chemical Engineering, UCT.

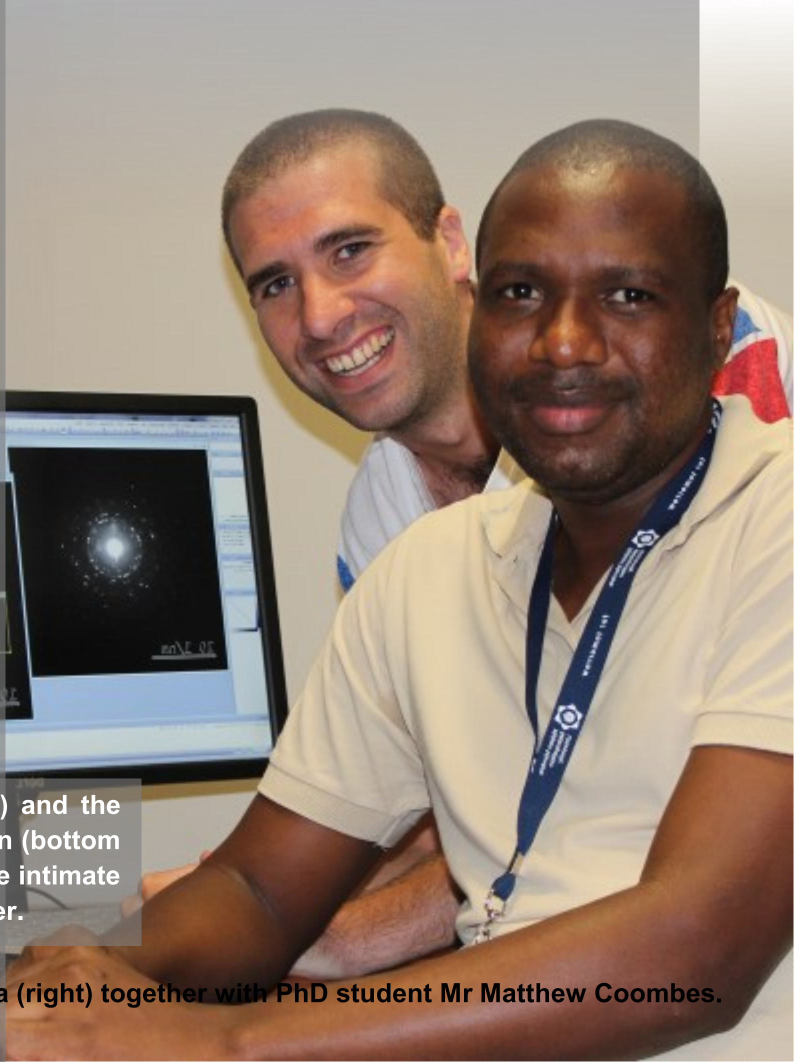


The Fischer-Tropsch (FT) process is invaluable to South Africa. It involves the reaction of syngas – a mixture of carbon monoxide and hydrogen – to produce a wide variety of hydrocarbon products, which includes petrol and diesel. The FT process consists of a number of different chemical reactions that occur in the presence of a suitable catalyst. Iron is a very common catalyst used in the FT process, very often prepared by adding silica as a structural promoter. These iron catalysts are prepared and stored as iron oxides, usually ferrihydrite, and need to be reduced to active catalyst particles within the reactor. CHRTEM postdoctoral fellow Dr Colani Masina and PhD student Mr Matthew Coombes (below) are using advanced microscopy to better understand these processes. Their research employs a variety of techniques, including high resolution transmission electron microscopy (HRTEM), electron energy loss spectroscopy (EELS), energy dispersive X-ray spectroscopy (EDS) and electron diffraction (ED).

Dr Masina's work is focused on elucidating the complex crystal structure of nano-crystalline ferrihydrite. Knowledge of the crystal structure of ferrihydrite and its reduction mechanism in hydrogen atmosphere is very important in choosing the best suitable chemical and structural promoters for real iron catalysts employed in FT synthesis. It is known that the presence of silica as a structural promoter makes it difficult to reduce ferrihydrite to the FT-active metal phase and his work also investigates the role that silica plays in the thermal transformation and reduction of ferrihydrite.

Mr Coombes' work is focused on understanding the fundamental interactions that occur between the ferrihydrite and the silica structural promoter which result in a more difficult to reduce catalyst precursor. Recent results shows that iron and silicon are very intimately related (see figure) during the preparation of these catalyst particles, which results in the formation of silicon-iron phases during reduction that are very difficult to further reduce to FT-active metallic iron.

Electron micrographs showing iron oxide particles (top left) and the distribution of oxygen (top right), iron (bottom left) and silicon (bottom right) within the particles. These micrographs demonstrate the intimate relationship between the iron and the silica structural promoter.



Postdoctoral fellow Dr Colani Masina (right) together with PhD student Mr Matthew Coombes.

ULTRA-HARD MATERIALS

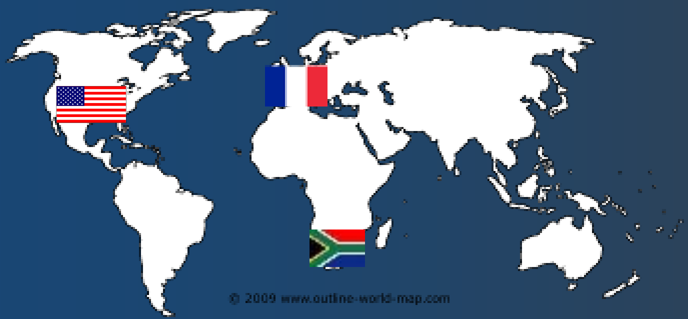
COLLABORATORS

- DST CoE in Strong Materials, Wits

The Centre collaborates with the DST Centre of Excellence in Strong Materials hosted by Wits University. Key materials investigated include poly- and nanocrystalline diamond products (PCD and NCD) used as drill bit inserts for oil and gas drilling, hard materials and hard metal alloys used as cutting and machining tools (e.g. in the mining and automotive industries), and diamond used in high-speed electronics. The properties of these materials depends on their micro and nanostructures and TEM and HRTEM at NMMU are used for the nano and atomic scale analysis of these materials.

PCD is used as drill bit inserts for oil and gas drilling.

TITANIUM ALLOYS



COLLABORATORS

- NMMU Department of Mechanical Engineering
- Department of Materials Science and Engineering, The Ohio State University, USA
- SiMaP, Grenoble, France

Locally, the Centre is collaborating with the Department of Mechanical Engineering at NMMU on the characterization of friction stir welded (FSW) joints of materials consisting of titanium-aluminium-vanadium alloys (Ti-6Al-4V), high strength low alloy steel and aluminium alloys with important applications for the aerospace industry, Eskom and the automotive industry. FSW is a relatively new solid-state joining process. It can be used to join aluminium, titanium and other alloys that are difficult to weld by conventional fusion welding.

Internationally, research is focused on advanced electron microscopy techniques and materials modeling. The Centre is collaborating with Prof Hamish Fraser from The Ohio State University on the analysis of beta titanium alloys supplied by Prof Fraser. Prof Mike Lorretto from the University of Birmingham, UK is also involved in the project. A new collaboration has also been initiated with Prof Muriel Veron at SiMaP in France.

HONORARY PROFESSOR
Prof H Fraser
Center for the Accelerated Maturation of Materials
The Ohio State University, Columbus, USA

BIOLOGICAL AND BIOMEDICAL MICROSCOPY

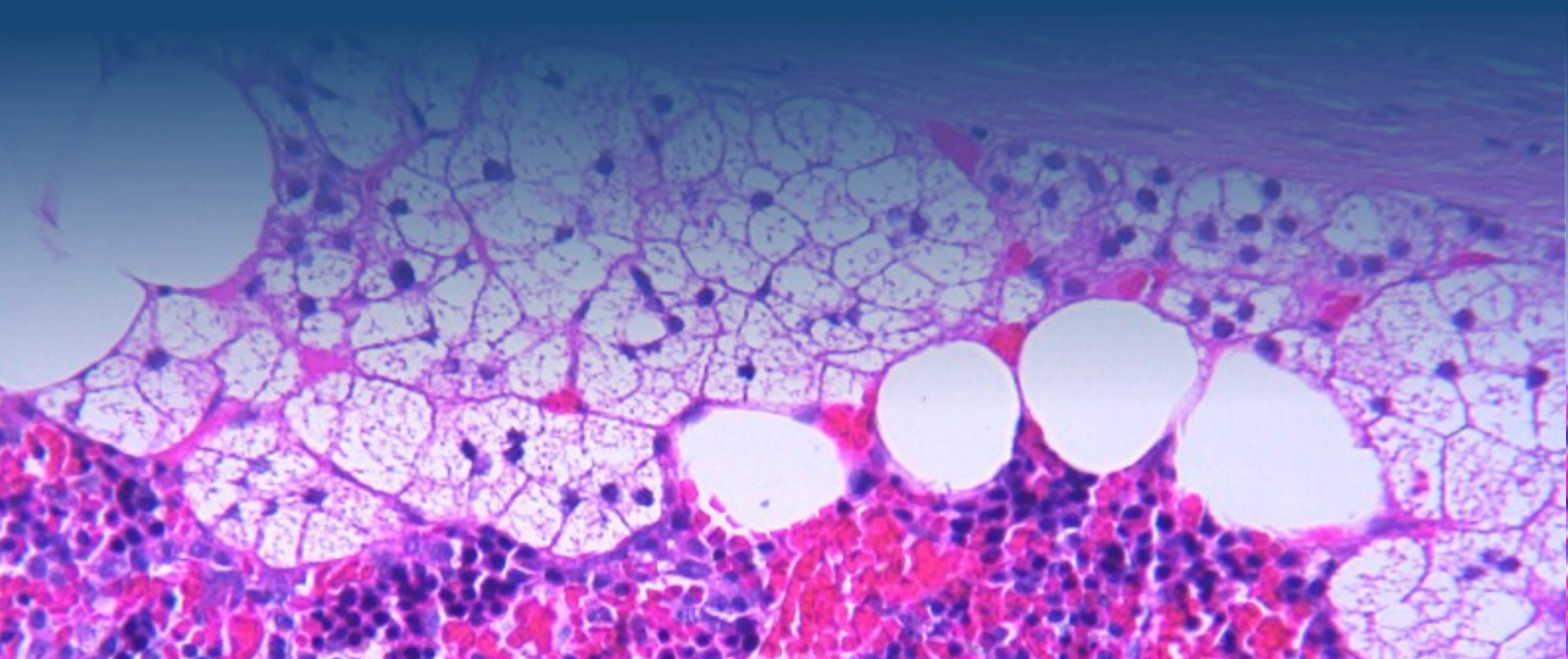
COLLABORATORS

- NMMU Department of Microbiology and Biochemistry
- Department of Biotechnology, University of the Western Cape

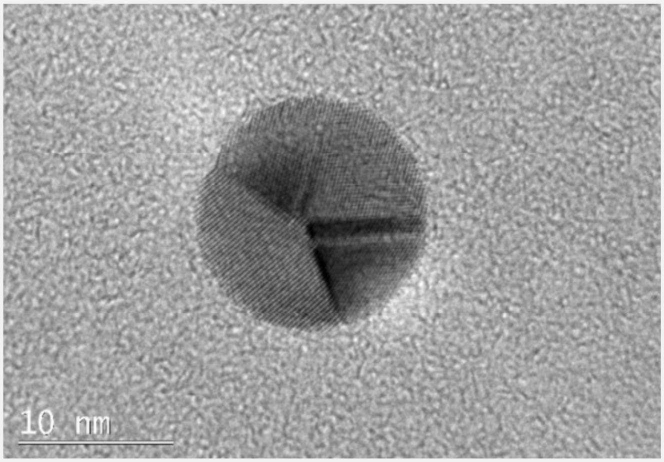
Biological microscopy – with an emphasis on both environmental and medical applications – is emerging as an area of interest at the Centre for HRTEM.

NANOBIOMEDICAL SCIENCE

The specialisation of nanobiomedical science forms an important part of the DST supported MSc Nanoscience degree **(www.nanoscience.ac.za)** that is presented jointly by the NMMU, the University of the Western Cape, the University of the Free State and the University of Johannesburg. To this end, the Centre has embarked on developing capacity in biological and biomedical TEM to support research collaboration between NMMU and UWC. A cryo-ultramicrotome and critical point dryer were acquired for the preparation of scanning and transmission electron microscopy nanobiomedical specimens. This instrument will be used by researchers in the biological, biomedical, polymer and hydrogen fuel cell sciences.

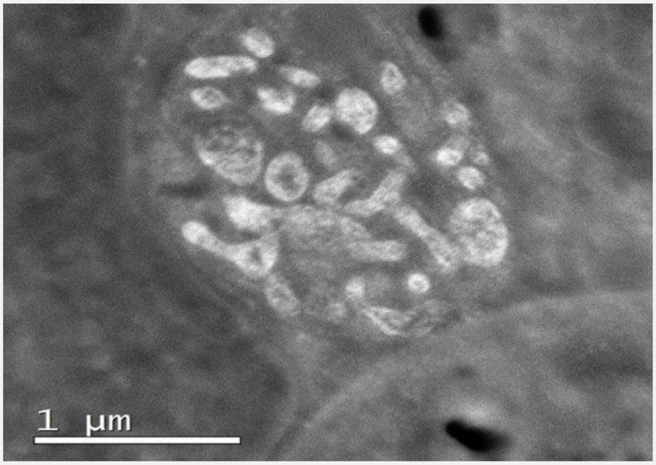


RESEARCH FEATURE

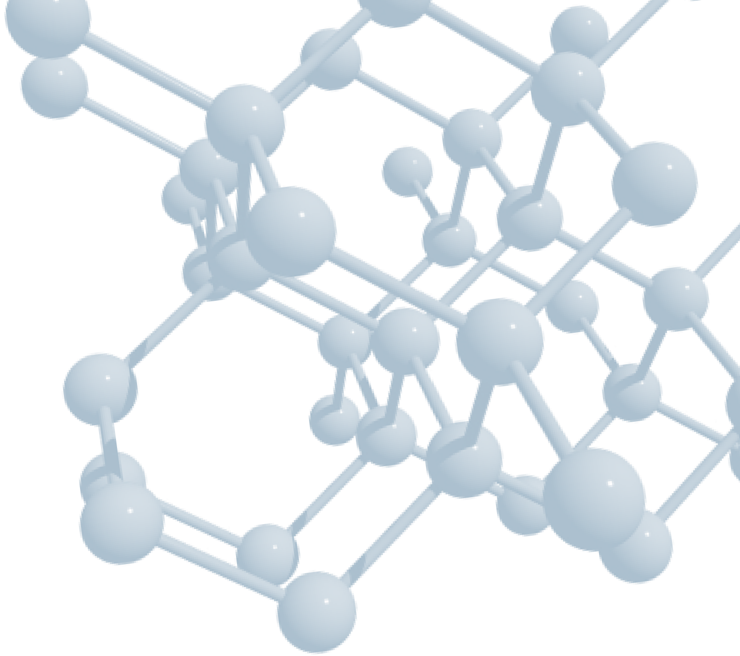


Bright field transmission electron micrograph of a colloidal gold nanoparticle with size 13 ±3nm.

The MSc Nanoscience project of Ms Lynn Cairncross focused on the use of microscopy to study the effectiveness of gold nanoparticles for diagnostic purposes. Colorectal cancer (CRC) is the third most common cancer and cause of related deaths worldwide. Research has indicated that stage I, II and III disease have a 5 year survival rate of 93.2%, 82.5% and 59.5% respectively compared with an 8.1% survival rate of patients having stage IV disease. Early CRC diagnosis is vital in reducing incidence and mortality. Traditional diagnostic tools such as colonoscopy or fecal occult blood tests may improve survival rates. However, these methods lack in sensitivity and specificity and are limited in relation to their cost, risk, and invasiveness. The knowledge of biomarkers and nanotechnology creates a powerful diagnostic platform. Gold nanoparticles (AuNPs) have gained much interest in cancer research due to their unique properties. Gold is essentially inert and non-toxic. Its surface may be modified with biomarkers for targeting and it possesses unique optical properties feasible for biological imaging. Previous studies have shown the specific binding of three peptides to CRC cell lines. However, their localization in an *in vitro* and *in vivo* CRC model has not been determined yet. The aim of this study was to elucidate the binding and localization of these three peptides functionalized to AuNPs using high resolution transmission electron microscopy (HRTEM).



HAADF image indicating the presence of AuNPs in a healthy kidney.



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