THE CENTRE FOR HIGH RESOLUTION TRANSMISSION ELECTRON MICROSCOPY

NELSON MANDELA METROPOLITAN UNIVERSITY, PORT ELIZABETH

Implications that HRTEM will hold for Research in South Africa and the Region

The main aim of the Centre for High Resolution Transmission Electron Microscopy (HRTEM) is to provide a broad community of South African scientists and students with a full range of state-of-the-art instruments needed for nanoscale materials research.

The Centre for HRTEM was established with the backing of the Department of Science and Technology (DST) after the national nanoscience community supported the establishment of the Centre at the NMMU due to its acknowledgement as a leader in the field of electron microscopy. The only double aberration corrected atomic resolution TEM on the African continent is housed in the Centre along with three other state-of-the-art electron microscopes and sophisticated specimen preparation equipment. The other instruments include a second fully analytical TEM with a resolution of 0.23 nanometre, a dual beam (electrons and gallium ions) scanning electron microscope and an analytical high resolution scanning electron microscope which is used mainly to study the surfaces and composition of materials.

The key objectives of the Centre for HRTEM are to conduct the most advanced nanoscale materials research on the African continent using an analytical atomic resolution transmission electron microscope and related instruments, and to train highly skilled MSc and PhD graduates. Secondly, it aims to transfer expert knowledge to industries and hence assist industry to bridge the gap between research and product commercialisation which will significantly contribute to economic development and international competitiveness of some South African companies.

Scope of the Centre's activities:

The equipment will be used for multidisciplinary research covering aspects of nanophysics, nanochemistry, materials science and mechanical engineering. Research and characterisation will be carried out on a wide range of materials, including ceramics (SiC, ZrC, ZrN), nanoparticle catalysts, nanophosphors, semiconductor quantum wells and dots, infrared detector devices, polycrystalline diamond products, single crystalline diamond, WC-VC-Co hard metals, metal alloys (titanium-aluminium-vanadium alloys), nuclear grade graphite, oxide dispersion strengthened ferritic steels and geological samples.

Current collaborators include the DST Nanophotonics Research Chair group at NMMU; the Nuclear Energy Corporation of South Africa (NECSA); Sasol; the DST Centre of Excellence in Strong Materials hosted by the University of Witwatersrand; the Department of Process Engineering, University of Stellenbosch; the Joint Institute for Nuclear Research in Dubna (Russia); Element Six; Mintek; Mechanical Engineering Faculties at NMMU and the University of Cape Town; the Physics Department at the University of the Free State; Rhodes University; the Chemistry department of the University of Johannesburg; Idaho National Laboratory (United States) and Oxford University (United Kingdom).

Prof Jan Neethling, Director of the Centre for HRTEM

Human Capacity Development:

The focus of training at the Centre will be on training postgraduate students in advanced TEM and HRTEM skills. It is estimated that over 550 students will be trained within 10 years, significantly increasing the skill base in South Africa.

Undergraduate training will be addressed by the National Teaching Initiative through the Stakeholder Forum, a forum created to discuss technical issues, common problems and the future of HRTEM, including curriculum development. This will address the shortage of skills in this area and ensure that students are adequately prepared for postgraduate studies. Specialist courses will also be run at the Centre.

Funding of the Centre:

The funding for the establishment of the R120 million Centre for HRTEM was provided by the Department of Science and Technology, the Department of Higher Education, NMMU, Sasol, NMMU Trust and Dr Greg Olsen (USA).

Additional information about scientific collaboration: External linkages involved in the Centre for HRTEM: NMMU linkages

- **Geology**

  TEM and HRTEM are important tools for modern mineralogy. TEM is particularly useful for studying very small crystals, lattice defects and submicron inclusions in larger minerals. The possibilities that the information gained at nano-level might be linked to physical events such as slope failure or ore formation processes will increase the use of TEM in the geological sciences. TEM can be used to identify fault surfaces which may have slipped in the past during earthquakes. The Centre for HRTEM assists the geology departments of the Universities of Cape Town and Bloemfontein and the NMMU with nanoscale analysis of geological samples.

SAASTA CERTIFIED

NRF National Research Foundation | SAASTA South African Agency for Science and Technology Advancement

- **NMMU Departments of Botany, Zoology, Chemistry, Biochemistry, Pharmacy**

  The Electron Microscopy section in the Physics Department has since 1995 assisted academics and postgraduate students from the abovementioned NMMU departments with electron microscopy investigations. The Centre for HRTEM will continue with this assistance to other NMMU departments subject to the approval by the Management Committee.

- **NMMU Department of Mechanical Engineering**

  A very promising collaboration with the Automotive Components Technology Station of the Mechanical Engineering Department at NMMU under leadership of Prof Danie Hattingh has been initiated. This project focuses on the characterisation of friction stir welded joints of materials consisting of titanium-aluminium-vanadium alloys (Ti-6Al-4V), high strength low alloy steel and aluminium alloys. This project has important applications for the aerospace industries, Eskom and the automotive industries and has great potential to leverage THRIP funds and generate publications.

External research collaborations

- **DST/Mintek Nanotechnology Innovation Centre**

  The Centre for HRTEM is assisting the Biochemistry Department at the University of the Free State with the TEM characterisation of nanogold and nanoplatinum particles for catalyst applications. These projects are funded by the DST/Mintek Nanotechnology Innovation Centre. Titanium alloys are also characterised for Mintek.

- **Optoelectronic semiconductor materials development at NMMU**

  Metalorganic Vapour Phase Epitaxy (MOVPE) is a technique by which thin semiconductor layers are grown atomic layer by layer to form a nearly perfect crystalline device structure. The MOVPE research group is managed by Prof JR Botha, who has been awarded a DST Nanophotonics Research Chair. Thin semiconductor films, quantum dots and nano-sized islands are grown by MOVPE at NMMU. The projects are funded by Armscor, the Advanced Manufacturing Technology Strategy (AMTS) of the Department of Science and Technology, the National Research Foundation and the National Laser Centre. The focus is on the development of optical sensors operating in the ultraviolet and mid-infrared, for application in the automotive and aerospace sectors. TEM and especially HRTEM are needed for the characterisation of all the semiconductor nanostructures grown at NMMU.

- **DST Centre of Excellence in Strong Materials**

  The Centre for HRTEM collaborates with the DST Centre of Excellence in Strong Materials, hosted by Wits University. The properties of these hard materials and hard metal alloys used as cutting and machining tools (e.g. in the mining and automotive industries), depend on their micro and nanostructures. In addition, the Centre looks into carbon nanotube composite materials, ceramic materials and materials with low and negative thermal expansion parameters. TEM and HRTEM at NMMU are used for the nanoscale characterisation of these materials.

External industry linkages

- **Sasol**

  Sasol collaborates with the Centre for HRTEM in the field of nanoparticle catalyst research and in the training of PhD students in nanomaterials characterisation using TEM and HRTEM. The HRTEM is essential for research on catalysts to improve the efficiency of Sasol's coal-to-liquids technology.

- **Element Six**

  The research carried out in the Centre for HRTEM is of benefit to Element Six for the development of new products, as well as the training of PhD students. The properties and reliability of the polycrystalline diamond products used in cutting tools and oil drill bits depend on the strength of the bonds keeping diamond particles together. The characterisation and development of these diamond tools rely heavily on nanoscale investigations using high-resolution electron microscopy.

- **Characterisation Coated Particle Fuel for High Temperature Reactors**

  The Centre for HRTEM has been involved in cutting-edge strategic contract research for the Pebble Bed Modular Reactor (PBMR) company. The project focused on the characterisation of coated nuclear fuel particles and graphite pebbles, and research on fission product transport in coated particles. The knowledge of fission product transport, i.e. how radioactive fission products created during the splitting of uranium migrate through the coating layers of the fuel particle, will enable nuclear scientists to improve the design and safety of fuel particles. The Centre will continue with this research in collaboration with international partners and the Nuclear Energy Corporation of South Africa (NECSA). NECSA has been tasked by the Department of Science and Technology to develop a Nuclear Energy Strategy for South Africa.

- **Nuclear Energy Corporation of South Africa (NECSA)**

  The Centre for HRTEM collaborates with NECSA on the characterisation of plasma dissociated zircon. This is an example of the beneficiation of a South African mineral. The mineral zircon is a primary source of zirconium which is used in zirconium alloys in the core of nuclear reactors. Other collaborative projects with NECSA include the analysis of irradiation damage in neutron irradiated materials which have important applications for nuclear reactor safety.

With thanks to Prof Jan Neethling from NMMU for providing the information for this fact sheet. This fact sheet has been reviewed by independent experts and has followed SAASTA's Scientific Editorial Process.