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SOUTH AFRICA'S COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH

Research and development for industry: Advanced manufacturing

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Mastering advanced manufacturing approaches: The key to competitiveness

The manufacturing sector is central to the economic well-being of South Africa. Second only to finance, real estate and business services as the largest contributor to Gross Domestic Product (2011, Q4 statistics), manufacturing plays a vital role in the economy of our country.

The desire to further increase our manufacturing output is set against highly competitive global conditions; often referred to as the 'competitiveness squeeze'. As a scientific and technological research and development (R&D) organisation, we believe that mastering advanced manufacturing approaches such as additive manufacturing, micromanufacturing, biomanufacturing and nanomanufacturing is what will ultimately determine whether our nation manages to rise to the challenge.

The CSIR's broad range of multidisciplinary competences is particularly valuable in the context of advanced manufacturing. Competences in diverse fields such as sensors, robotics, bioprocessing, smart materials, laser technology, micromanufacturing, nanotechnology and information and communications technology all add up when it comes to addressing challenges in this area.

It is against this backdrop that the CSIR has formulated its R&D strategy for advanced manufacturing. The organisation will focus its resources in this area on those sectors identified as national priorities and to which the organisation's competences are well-suited. Examples of such sectors include metals processing, automotives and aerospace. Sectors with significant growth potential such as electronics, pharmaceuticals and agroprocessing have also been prioritised.

Very specific aims include the establishment of a titanium industry (read about this on pages 26-35) and the optimisation of additive manufacturing, an emerging technology that makes possible the fusion of materials into three-dimensional, functional, near-net-shape parts (see pages 12 and 13). Contributing to a biomanufacturing industry, with significant potential benefits for rural development and new enterprises remains a priority. The dividends of investment in this domain are evident in a number of products at different stages in the development pipeline (see page 38). A hint of the potentially profound impact of microtechnologies on practically all industrial sectors is captured in an article on page 58, outlining the progress with manufacturing self-immobilised enzymes through droplet microfluidics. Advances in materials science are enabling the development of materials with superior properties resulting in new products and even new industry sectors (pages 11, 48 and 49).

Research, development and innovation (RDI) must play a greater enabling role in the South African manufacturing sector. We embrace this opportunity and responsibility. We will continue to develop strategic partnerships with stakeholders in the national system of innovation to strengthen our collective capability. In assessing the current landscape, we are optimistic that our organisation, and the broader RDI community, can make a significant contribution to the size, competitiveness and sustainability of the South African manufacturing industry.

Dr Sibusiso Sibisi,
CSIR CEO

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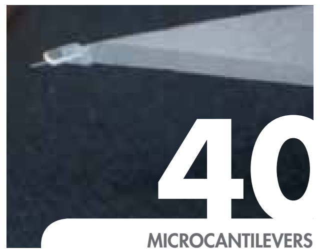
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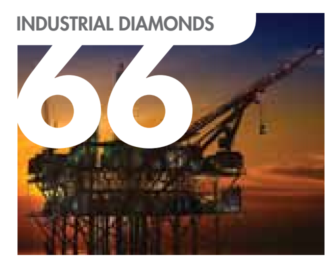
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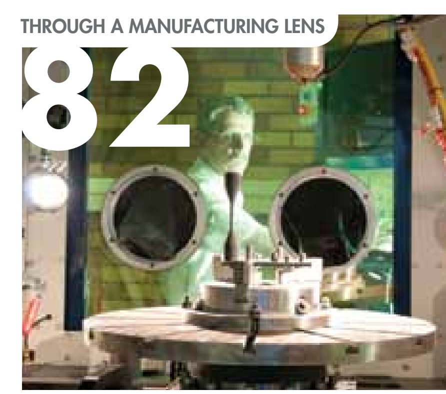
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News snippets from around the CSIR

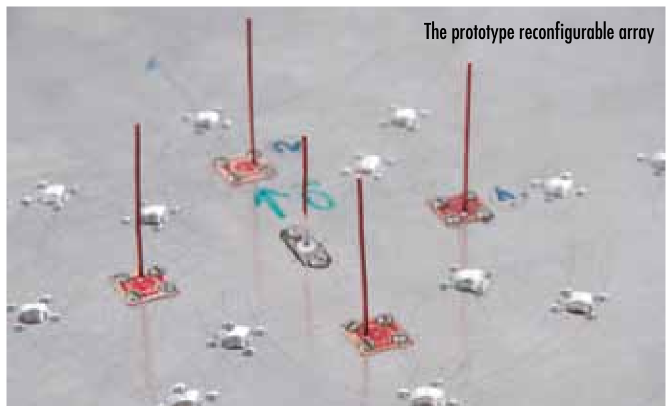
CSIR and Nestlé announce research partnership

THE CSIR recently signed a ground-breaking research partnership with Nestlé.

The partnership is aimed at contributing to research and development work based on indigenous South African biodiversity to evaluate the potential for nutraceutical and functional foods with proven health benefits.

CSIR CEO, Dr Sibusiso Sibisi, said: "The joint venture will give CSIR scientists access to international technologies in the field of nutraceuticals – functional foods with demonstrated health benefits. It will also enhance our capacity in better understanding of industry development cycles and requirements for the commercialisation of such products. In addition, this will add value to our indigenous resources through exposure to modern technologies in developing new food-based products."

"New products developed through this collaboration will be manufactured in South Africa in compliance with international standards, leading to development of new skills and ultimately creation of new jobs in the biosciences industry," Sibisi concluded.



The prototype reconfigurable array

The antenna gain: Power saving and longer life for autonomous smart systems

CSIR RESEARCHERS have identified a new concept, based on the use of ultra-low-power array antennas, which can potentially reduce the power consumption used for radio frequency (RF) transmission in wireless sensor network devices by an order of magnitude. This offers a much longer life for these systems. Initial estimations are promising: 0.36 milliwatt (mW) measured consumption per array element, and support of 30 mW of RF power. The team sees a possibility to reduce the consumption even further, while substantially reducing the antenna's size and weight, and is set to measure the power savings directly in the upcoming months.

– Biffy van Rooyen

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Innovation in camouflage now protects against predators, pests – and the sun

THE CSIR HAS DEVELOPED camouflage netting that not only helps a person or object 'blend in with the scenery', but also features insect-repellent properties as well as UV protection. The net fabric was selected so that the product is lightweight for easy storage and transportation. The camouflage can be customised further to deal with summer or winter landscapes.

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CSIR conducts research on energy efficiency and thermal comfort

CSIR RESEARCHERS will use temperatures recorded and monitored in a demonstration house built on the CSIR campus by BASF, and use a simulation model to calculate the energy requirements for heating and cooling the house. The CSIR will measure energy efficiency and simulate thermal comfort inside the building by using data collected from a weather station installed on the CSIR site. The project is of particular interest as it is one of the most highly insulated houses that one could reasonably build in South Africa. The research results will show the thermal performance delivered by the insulation in the house under South African conditions and provide a best-case scenario for energy efficiency in the local residential sector.

CSIR project leader Llewellyn van Wyk and Dr Dieter Kovar, MD of BASF Holdings SA at the BASF demonstration house handing-over ceremony

SPECIALISED EQUIPMENT AT INDUSTRY'S DISPOSAL

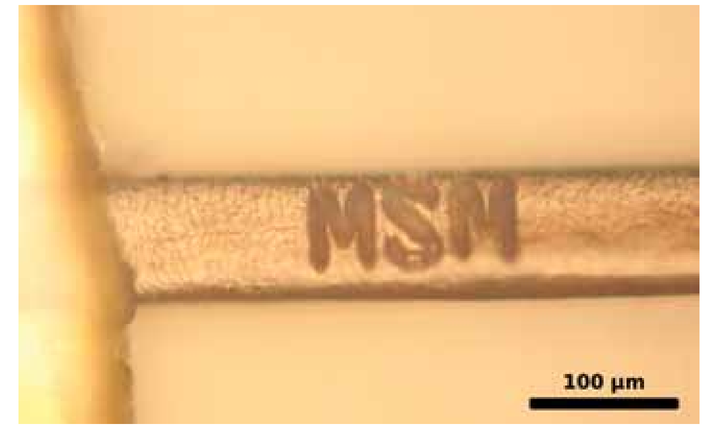
Laser micromachining for precision engineering

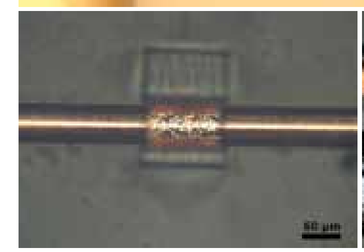
EXCIMER LASER MACHINING systems are ideally suited for micromachining applications in industry. This includes application areas such as wire stripping, hole drilling, and thin-film patterning, used for medical applications, semi-conductors and ink jet printing. These systems can machine in most materials, including polymer, glass, metals and ceramics.

The CSIR's mechatronics and micromanufacturing group has a Resonetics excimer laser micromachining station with an average power of 80 W at a wavelength of 248 nm, and 45 W at 193 nm, making it an ideal tool for the applications mentioned here.

The system is currently housed at the CSIR National Laser Centre to enable the use of the system in conjunction with other laser micromachining systems.

If you are interested in using this equipment, please contact Louis Fourie at **lfourie@csir.co.za**.





The top photograph shows a human hair with the letters MSM machined into it. This shows the capabilities of the system, right, in terms of machining accuracy and size. The bottom left image shows a 60 µm transformer wire from which the polymer isolation coating has been selectively removed to expose the core material.

Forming an image of surface deformations

AS PART OF THE CSIR'S INVESTMENT in research equipment, the organisation purchased a PSV-400-M2-20 high-frequency scanning vibrometer system from Polytec. The vibration measurement makes use of a non-contact laser-Doppler technique, with a relatively large stand-off distance possible. It is capable of measuring tiny displacements smaller than a nanometre at high frequency.

The scanning system automates the process of performing vibration measurements sequentially over a grid of points and then combine them to form an image of surface deformations. Generally, for scanning vibration measurements, a repeatable input excitation is required.

The system is ideal for experimental modal analysis, but has many other applications in industry. The system is currently being used to support the development of piezoelectric actuators and motors as well as ultrasonic transducers for guided wave ultrasound in rails.

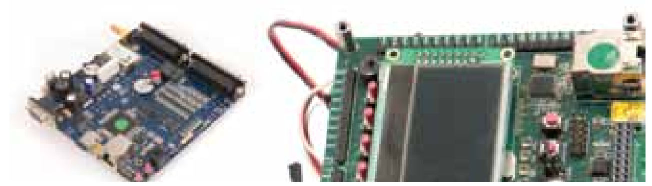
If you are interested in using this equipment, please contact Dr Philip Loveday at **ploveday@csir.co.za**.

Green Mamba control board for high performance

GREEN MAMBA is a high-performance embedded control board developed by the CSIR. The board is based on ATMEL's AVR®32 which gives it high performance at low power consumption. It runs the FreeRTOS real-time embedded operating system.

The Green Mamba CPU board is part of a stackable system of expansion boards through a standardised stacking connector. The CPU board (top of every stack) has a large number of features, which include Ethernet, USB, micro-SD card, LCD display, 4 serial ports, 8 digital inputs, 8 digital outputs, 8 analog inputs, etc. Additional boards are available as standard expansions for the architecture. These include boards with communication (GSM, Bluetooth®, GPS, etc.), motor control, battery monitor/charging, high-speed analog-to-digital capture, etc.

Anyone interested in using this technology or obtaining full features, can contact Peter Bosscha at **pbosscha@csir.co.za**.



The Aerospace Industry Support Initiative:

Providing industry with skills and scope to soar

South Africa has a vibrant aerospace sector – the largest on the continent – and one known for quality research and manufacturing, as well as extremely high testing and evaluation standards. A hotbed of technological innovation, the sector is also known for creating scope and opportunities for skills development and the stimulation of smaller businesses – building blocks to a healthy South African economy.

Marié Botha, AISI programme manager

A KEY CONTRIBUTING FACTOR to this robust aerospace industry is the active and tangible collaboration between government, industry, the scientific community and international aerospace and space players. The Aerospace Industry Support Initiative (AISI) is one example of a government-funded mechanism which exists to support the local South African aerospace industry. Established by the South African Department of Trade and Industry (**the dti**), the AISI became operational in 2005 and is managed and hosted by the CSIR.

The express aim of the AISI is to see to the health of the local aerospace industry and its positioning as an active and valued player in the global aerospace industry. The AISI places specific emphasis on supplier development, industry development and technology support, and creating a platform for industry collaboration.

The AISI operates six programmes, namely:

- New industry development and technology support
- Supplier development
- Industry and impact studies
- Space regulation and human capital development
- Sector strategic support initiatives programme
- Coordination, promotion and awareness.

Marié Botha, programme manager of the AISI says that the approach is to facilitate the creation of linkages and strategic partnerships within the local aerospace sector; as well as with global stakeholders, to acquire skills and technologies. These alliances allow for the improvement of existing technologies; and simultaneously mastering the production and process technologies needed to build new sustainable platforms. This requires a change in the paradigm from the traditional, static client-contractor-type relationship to one where the client becomes a close partner.

The role of the AISI as an industry support mechanism is to:

- Increase the contribution of small enterprises to the economy
- Significantly enhance Broad-Based Black Economic Empowerment
- Raise the levels of direct investment overall, as well as in defined priority sectors
- Increase market access opportunities for, and export of, South African goods and services
- Contribute towards building skills and technology platforms
- Improve the local industry's competitiveness
- Ensure that new technologies are taken up by industry through an active process of innovation.

Botha says that new industry development and technology support projects undertaken in collaboration with local industry include projects such as the development of fibre metal laminates for aerospace applications, where titanium and carbon fibre-based materials with high impact resistance are developed, suitable for unmanned aerial systems (UAS) and satellite applications (see article on page 11). In another project, the development of a stiffness-tailored UAS wing is in progress, with the aim of developing a methodology for the structural design of wings based on the stiffness (deflection and rotation) requirements obtained during the optimal aerodynamic design, and the application of that design to a UAS wing (see article on page 10). A laser shock peening (hardening) initiative with the goal of establishing laser shock peening infrastructure in South Africa aims to ensure the uptake of this technology by the aerospace and related industries.

Furthermore, the AISI supported the acquisition of state-of-the-art laser-based additive manufacturing infrastructure, which will ensure South Africa's future competitiveness in the aerospace industry. The Optomec LENS 850-MR 7 system is specifically configured to address the needs of the South African aerospace industry and research and development community (see article on page 12).

The AISI also assists a local aerospace original equipment manufacturer (OEM) with a project to transfer airline galley design, certification and manufacturing capability to two local small, medium and micro enterprises. This is as a result of the manufacturer withdrawing from the galley supply business, but not wanting the capability and know-how to be lost to the local industry (see overleaf).

Another project builds on capability already created to manufacture thermoplastic frame clips for the Airbus A350, and involves the development and optimisation of forming and tooling methodology for multi-shaped parts, the high speed dimensional inspection of parts; a high-speed non-destructive testing inspection system, and the creation of a semi-automated edge-sealing system.

Lastly, the AISI supports the development of deep-drawn press technology for the Airbus A350. This project comprises two activities namely, the pressing of large tubular parts, and the automation of pressing parts; and documenting effective process control, procedures and process documentation. The AISI ensures that technology filters down to lower tier suppliers, by ensuring that South African OEMs involved in AISI-funded projects enlist at least one local SMME industry partner. Process and supply chain optimisation, when implementing these projects, is undertaken through the AISI's supplier development programme.

Botha says that the AISI benefits from access to CSIR scientists in the fields of aerospace, Earth observation, laser technology, metals, materials and manufacturing, as well as facilities such as wind tunnels. In turn, the CSIR has improved its ability to direct its multidisciplinary competences at those nodes in the South African aerospace industry that require technological intervention.

The CSIR has a track record of establishing and hosting initiatives and programmes that contribute to economic development. Past examples include the establishment and hosting of the South African National Space Agency, the Automotive Industry Development Centre, the National Cleaner Production Centre, and the National Foundry Technology Network.

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Focus on supply chains and logistics for the aerospace industry

CSIR researchers are conducting a number of interrelated studies on supply chain and logistics for the aerospace industry. A snapshot is given of these projects undertaken for, and supported by, the Aerospace Industry Support Initiative (AISI).

Analysis and benchmarking

Within the supplier development programme of the AISI, researchers are collecting supply chain data from organisations in the South African aerospace and defence industries. The data will enable organisations in these industries to benchmark themselves against similar companies.

Benchmarking data are being collected from various organisations within the industry, and benchmark values calculated. The benchmark results can be used by organisations as tools to identify potential areas for improvement in their supply chains.

Costs

The supply chain and logistic costs of organisations in the aerospace and defence industries are being quantified by the CSIR. An analysis will be done of specific logistics cost-areas in companies, including areas such as transportation, warehousing, inventory and administration costs.

Such data will assist decision- and policy-makers in the public and private sectors to better understand the various components of logistics costs in the industry and enable them to identify potential areas where the industry's performance and cost effectiveness could be improved, thereby contributing to its global competitiveness.

Geospatial clustering

Supply chain data can be linked to the spatial data being collected by the CSIR for the geospatial clustering of the aerospace industry. The geospatial clustering project resides within the AISI's supplier development programme.

The various aerospace small, medium and micro enterprises (SMMEs) will be mapped to provide the industry with the geographical distribution of those small enterprises. Linked to each location will be the name of the enterprise as well as the type of products it manufactures. The locations can be used to determine accessibility of these SMMEs to the industry as well as to provide input to determine the optimal locations of new industry developments.

The geographic locations of the SMMEs and industries will be the base data for supply chain management as well as any other planning activities relating to the aerospace industry. Such data will also be used as input to develop and populate the supply chain operations reference model.

Green audit

South Africa's green house gas (GHG) emissions per capita and its GHG emissions per unit of gross domestic product (emission intensity) are nearly twice those of the world average. Green supply chain management is essential in today's world, and ensures good business practices as well as environmental sustainability.

The carbon footprint of the local aerospace and defence industries is being determined by CSIR researchers. A systemic approach and comprehensive methodology will be applied and the GHG Protocol Corporate Standard will be used to audit how 'green' the South African aerospace supply chain is.

Some companies have the perception that transforming to a sustainable, green supply chain could result in reduced profit margins, due to increased costs for buying and implementing new environmentally friendly equipment, technologies and process measures. However, research results and actual business implementations are showing opportunities for increasing value and saving money by reducing energy consumption and waste, and improving efficiencies and performance.

The effective greening of supply chains necessitates a holistic systems and network assessment that should lead to life-cycle optimisation. The entire supply chain is analysed for inputs and outputs at each stage. Raw material, energy and financial inputs to the system – as well as waste outputs – are minimised, while production and financial outputs are maximised. The desired result is green cost savings and process improvement in the South African aerospace and defence industries.

Results

The AISI will make the results of all the CSIR studies and proposed future improvements available to the aerospace industry and publish these on the AISI's web portal.

– Hilda van Rooyen

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Towards a vibrant aerospace sector. Pictured from left are the experimental casting of a titanium part at the CSIR; a biocomposite material under development for an aerospace client; and the inside of the CSIR's medium-speed wind tunnel, where aerodynamics is investigated. Pictured below is the manufacturing of an airline galley at a local manufacturer.

Markus Coetzer

Reducing the development costs of UAVs

A cost-effective structural optimisation method is within reach, with a new software platform being developed at the CSIR that could reduce the number of design iterations required for aerodynamic structures.

CSIR ENGINEERS are building a software platform that allows for the design of an unmanned aerial vehicle (UAV) wing to ensure optimum performance. The CSIR has an extensive track record of building UAVs for military use.

Markus Coetzer, a CSIR structural engineer focusing on advanced materials, composites and smart structures, says that from their initial military use, UAVs are now finding their way into civilian applications. Coetzer says, "In the near future we will see UAVs being used for industrial applications." Already, the CSIR is working with Eskom to build UAV prototypes to inspect power lines.

In order to increase the performance of UAVs, aerodynamic optimisation of the wing is used, taking into account range and loiter targets. Designing successive iterations of the UAV wing to match the stiffness required for optimum aerodynamic performance is both costly and manpower intensive. The CSIR is developing a software platform where the required stiffness characteristics of an UAV wing can be fed into the system, resulting in less design iterations before the wing is physically built.

The platform will also be used to design other aerodynamic structures like wind turbine blades. "Efforts are underway to create a large-scale wind energy industry in South Africa, which requires a significant investment in the design, testing and manufacturing of wind turbine blades suitable for our region," says Coetzer. "Our software will be the ideal platform to reduce the cost of the design of such structures, thereby reducing the final cost," he concludes.

– Bandile Sikwane

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Gary Corderley

A strong new hybrid material that is also lightweight

By combining two or more completely different materials one can create a product that has all of the strengths and none of the weaknesses of those materials. In its quest to support the aerospace manufacturing industry, the CSIR is looking at different materials that will work best for aircraft.

CSIR RESEARCHER Gary Corderley is working on designing lightweight hybrid composite and metal materials that combine the advantages of both metals and composite materials.

He explains: "We are combining materials for example, by creating alternating layers of metal and carbon fibre; the metal being titanium. There are various materials that one can use to create such a new high-strength-low-weight material. We have gone with titanium because it works best with carbon fibre, and we have a great deal of expertise in working with titanium."

Among the biggest positives emerging from one of his newly created materials, is that it is extremely damage-resistant. This makes it perfect for use in the manufacturing of Unmanned Aerial Vehicles (UAVs). Corderley and his team are also looking at novel ways to combine a variety of materials that will easily navigate the difficult and very precise shapes needed for example, in the specifically tailored wings of these aircraft.

UAVs are a particular subset in the aerospace industry where the aircraft has the tendency to be damaged quite easily during normal operation. These aircraft are extremely lightweight, and like their man-operated counterparts, much of the bodywork needs to be quite intricately and precisely shaped. According to Corderley, there are ways to manufacture UAVs so that they are both lighter and tougher; his hybrid composite and metal materials being one of these ways.

"We also did a lot of work on optimising the material so that it can be applied in the manufacturing of very high-value low-volume products, where weight is a critical factor. An example would be satellites, or even specific areas on large aircraft that are prone to fatigue," he says.

The CSIR contracted the University of Pretoria for the polymer chemistry work. Corderley explains that this involved work around the adhesive used to bond the layers of titanium and carbon fibre.

To facilitate the successful development of the new material, a great deal of technology first had to be put in place. The group designed and installed several specific technologies geared at materials testing. These technologies became part of the CSIR's mechanical testing laboratory. Specific software packages that assist with the design and structure of composite materials also had to be developed and established.

"We are currently patenting the material development process and the material itself. With a growing UAV industry both in South Africa and abroad, along with several other applications that this material can be used for, we are positive about its uptake in industry," concludes Corderley.

– Petro Lowies

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Laser additive manufacturing:
Building SA's future one layer at a time

The CSIR is developing a suite of unique laser additive manufacturing systems and processes that will place South Africa at the forefront of this technology, with tremendous potential benefits for the local manufacturing industry.

COMPARED TO CONVENTIONAL manufacturing technologies which are often subtractive (materials are removed via cutting or milling), additive manufacturing relies on various energy deposition technologies to fuse materials into three-dimensional functional parts; materials are joined to make objects, one layer at a time. Laser additive manufacturing (LAM) allows for this to be done using lasers.

This emerging manufacturing technology lends itself to the development of components from unique ceramic, alloy and light metal materials. It will be key in the beneficiation of South Africa's titanium resources – around which efforts are being accelerated to establish a titanium industry – and affords the local aerospace industry a significant competitive advantage over international competitors. This innovative technology will be used for the production of unique finished goods for the aerospace, defence, automotive (in areas such as motor racing) and medical industries. It is against this backdrop that the CSIR has created a programme focusing specifically on additive manufacturing.

The goal of the additive manufacturing programme is to promote and advance the knowledge, capabilities, and economic opportunities in this field for the benefit of local industries. To achieve this objective, the CSIR will focus its resources on supporting three main initiatives in additive manufacturing.

Deputy Minister of Science and Technology, Derek Hanekom, third right, recently officiated at the launch of a new additive manufacturing facility at the CSIR. Also present were, from left, Dr Paul Potgieter, group managing director: Aerosud; Dr Federico Sciammarella, manager of laser materials processing, CSIR; Dr Ndumiso Cingo, manager of the CSIR National Laser Centre; Dr Sibusiso Sibisi, chief executive officer, CSIR; and Dr Hoffie Maree, group executive: operations, CSIR.

Laser metal deposition additive manufacturing (current state-of-the-art technology)

During 2012, the CSIR will establish an additive manufacturing workgroup, focusing on laser-engineered net-shaping (LENS) technology, with academia, industry and relevant government agencies.

"LENS technology uses a high-power laser (500 W to 4 kW) to fuse powdered metals into fully dense, three-dimensional structures," says Dr Federico Sciammarella, manager of laser materials processes at the CSIR.

"The LENS three-dimensional system uses the geometric information contained in a computer-aided design solid model to automatically drive the LENS process as it builds up a component, layer by layer," he notes.

Additional software and closed-loop process controls ensure the geometric and mechanical integrity of the completed part.

The goal is to identify critical components and industries, in addition to the identified target markets in aerospace and biomedics, that can benefit from either manufacturing or refurbishment/repair using LENS technology. The CSIR will be a key link and driver in coordinating and forging partnerships of potential users.

High-speed, large-area selective laser melting (cutting-edge technology development)

In a second project, called 'Aeroswift', the CSIR has teamed up with Aerosud, an established leader in the South African aviation industry.

The main goal of this project is to establish a functional first-generation, high-speed, large-area selective laser melting system that will be capable of building aerospace components with dimensions within a range of 2 m by 0.5 m. Such a system is currently not available commercially and therefore will have a niche market with high impact, as there are a variety of aerospace components that fall within these dimensions. Creating this technology in South Africa in collaboration with the Titanium Industry Initiative will contribute to South Africa increasingly becoming a key player in the aerospace sector.

Major aerospace companies have indicated that they are paying close attention to the success of this project, with 2016 targeted for a fully operational system, capable of producing its first parts. This would be a tremendous boost to the manufacturing sector in South Africa and would allow companies like Aerosud to expand their product range. It would also see South Africa cover the full value chain from a raw product (titanium powder) to high-value components.

Ultra-high-speed laser additive manufacturing (next-generation, radical design technology development)

For the third project, called 'Umuvi', the long-term objective is to create future generation high-speed, large-area, laser additive manufacturing systems, to stay ahead of the trend worldwide and capture future revenue streams by meeting future demands for more efficient and higher productivity systems.

Researchers and engineers from the CSIR National Laser Centre and Aerosud have teamed up for project Aeroswift. They are working to create a functional first-generation, high-speed, large-area selective laser melting system that will be capable of building aerospace components with dimensions within a range of 2 m by 0.5 m.

"The underpinning technology for all these projects is laser-enabled additive manufacturing and our LENS system will set the tone for the Aeroswift and Umuvi projects. The system enables immediate entry into the refurbishment market, where worn-out parts or components are repaired, and the working life or performance of the component becomes even better, compared to the original part," says Sciammarella. "If we succeed in showing the value of this technology, projects Aeroswift and Umuvi will be welcomed by industry," he adds.

"Successful completion of these initiatives will see the creation of a knowledge base and capacity that will enable South Africa to generate sustainable wealth and future opportunities in additive manufacturing," concludes Sciammarella.

Also read the article on page 84.

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Umuvi is an IsiZulu word for wasp: A winged insect that has a narrow waist and a sting. It constructs a nest from wood pulp or mud, pictured above (using the principles of additive manufacturing, left).

Cutting-edge laser technology **gives SA manufacturing the edge**

Laser cutting is one of the most successful machining applications and has gained a high level of maturity and global acceptance as an industrial process. This image, showing an automotive catalyst, demonstrates the capability of a 3D cutting laser housed at the CSIR.

The CSIR helps save the South African automotive industry millions of rands by increasing productivity and eliminating the need for downtime. The CSIR National Laser Centre is the only laser facility in South Africa that can do 3D laser cutting.

THE CSIR, through its laser-enabled manufacturing competence and enhanced by a range of powerful lasers including a 5 Axis laser-cutting system, has a 'force multiplier' effect on the local manufacturing industry, especially the automotive industry.

Elaborating on this statement, Hansie Pretorius of the CSIR says that the organisation's investment in state-of-the-art laser technologies, and a team of laser-based manufacturing experts, are keeping the organisation at the cutting-edge of technology development in this domain, to the benefit of the South African manufacturing industry. "Laser technologies enable us to save the South African manufacturing industry millions of rands on a yearly basis," says Pretorius. "We are aware, for instance, that the automotive industry is facing a challenge because of tight schedules, especially on tooling. We use laser systems to cut samples required by the manufacturers, while engineering shops are machining the tooling for a full production run."

Other components that the group cuts for this industry include catalytic convertor shells; heat shields; door members; and steering wheel assemblies.

To date, the group has done laser cutting, hardening, ablation and welding work for companies such as Mercedes Benz, VW/Audi, Ford, Nissan, Toyota and Maserati. Work was also done for Denel on the Rooivalk Attack Helicopter; Tupperware, and for various tooling manufacturers.

"Our main objective is to fully introduce laser technology by making systems available at the CSIR that industry can embrace into its production processes," says Pretorius.

For the automotive industry, for example, the group cuts samples for testing, which is followed by the cutting of the first 200 samples, so that the automotive manufacturers can start assembling vehicles.

"Our capability in this regard is unique, South Africa has no other three-dimensional (3D) laser cutting capability to assist industry in this way," says Pretorius.

"We have not had components that we could not cut," says Pretorius, "If it is a laser machinable component, we can cut it."

Advanced manufacturing, notes Pretorius, saves the industry cost and time. "We are able to run two processes simultaneously," he says. "While our industry partners build the trim tooling, we can produce components for production – with no associated downtime."

Pretorius admits that lasers are not always a quick solution, but the benefits lie in its precision, and the fact that it does not require any tooling.

At the forefront of laser hardening

"One of our biggest clients in laser hardening is Bell Equipment," says Pretorius. "For Bell, we do selective hardening on specific areas on stub axles."

"With our 5 Axis laser, we did 3D cube cutting for an engineering company that is involved in energy supply," he says, adding that this is impossible to achieve with a normal laser.

Pretorius is proud to say that the group's work can be seen in the new VW Polo line, where they did laser hardening on the styling lines of a bonnet press tool in order to perfect the product, before it was mass-produced.

Cladding for industry

This technique – deposition of a metal powder onto a surface using a laser – provides a 100% metallurgical bond between the layer and the base material. "We use cladding for refurbishment of turbine blades and compressor blades; and the repair of aircraft gear boxes, cylinder heads, shafts and tooling," he explains.

The three-dimensional laser cuts a Maserati part for MA Automotive Tool and Die, a client in the automotive sector.

CSIR operators Jacob Mojela, right, and colleague Andrew Madi are seen here laying out the component for laser 3D cutting.

Hansie Pretorius, manager, CSIR laser-enabled manufacturing, right, with Morné Kleinhans, left, and Pieter Bonthuis of MA Automotive Tool and Die, positioning a robotic arm that is used as a tool to align measurements for cutting.

Pictured at the CSIR facility where the Trumpf laser system is housed, are from left, Jacob Mojela, Pieter Bonthuis, Hansie Pretorius, Morné Kleynhans and Andrew Madi.

Parts cut or hardened using laser technology.

With laser cladding, worn parts are refurbished. Currently, many companies dispose of worn parts. “This is where we fit in,” says Pretorius. “We repair the worn-out parts for that particular client and by doing that we save the company the cost of buying new components, which often have to be sourced from abroad.”

“We offer a specialised, highly technical service to companies, where we repair samples for them to test and evaluate. If these tests are successful, we start with production,” Pretorius remarks.

With the technologies that they currently have, adds Pretorius, they can repair components whereby the working life or performance of these parts often outclasses the original part.

For instance, where a part is susceptible to corrosion, laser cladding technology can enhance the part to be corrosion-resistant, in addition to repairing it.

With all these lasers, the CSIR is able to repair parts in less than a day. Outlining the cost advantage, Pretorius says a new part could cost for example, R15 000, compared to a laser-refurbished part, ready to fit back into production, for R2 000.

Laser welding

“Laser welding’s advantage is that a smaller heat-affected zone with deep penetration is achieved,” notes Pretorius. “This limits distortion of components.”

This is arguably the most accurate technique in welding. The CSIR’s experts weld gears, rocket motors, and injection moulding tools. They welded on the joysticks of the Rooivalk Attack Helicopter.

The CSIR hopes to receive funding that will see its laser experts conduct feasibility studies to boost South Africa’s fledgling small, medium and micro enterprises (SMMEs).

“We have already done some work for a number of SMMEs,” says Pretorius.

Laser-enabled manufacturing has also been boosted by the arrival of the laser-engineered net-shaping system recently acquired by the CSIR. “This is a huge development for our industry, as we can now build components from a computer-aided design drawing,” concludes Pretorius.

– Mzimasi Gcukumana

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Laser technology at the desert beast’s service

THE CSIR SUCCESSFULLY repaired camshaft-bearing seats in an aluminium cylinder head, for the Toyota Auris S2000 rally cars participating in the SA National Rally Championship.

The cylinder heads were damaged during an event last year, and are now again race-ready to tackle the 2012 championship. The repair involved cladding of two halves of a cylindrical seat which were then bolted together and re-bored to final dimensions and surface finish.

The Aurises are stable mates of the Toyota Hilux bakkies which competed in the 10 000 km Dakar Rally in Argentina, Chile and Peru earlier in the year, pictured below. The Toyota Hilux bakkie finished third in the 2012 Dakar Rally.

Toyota South Africa also requested assistance from the CSIR to combat excessive wear observed on a forming tool used in the manufacture of bumpers. The organisation conducted experiments aimed at performance enhancement of these forming tools. The tools are meant to last for 15 years but at the present rate of wear, are set to fail prematurely. Sample material was supplied by Toyota which was successfully hardened.

CSIR enables Hallspeed to recoup damaged components

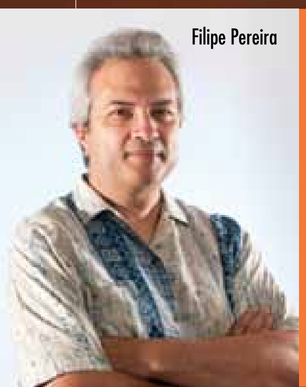
IN THE PAST, damaged parts were mostly thrown away, says Hallspeed technical specialist, William Haddad. Hallspeed is Toyota’s motorsport arm.

Outright disposal of worn-out parts is now something of the past. The company now repairs and refurbishes damaged parts by employing CSIR laser technology; restoring them to their former glory while saving the company money.

Haddad is in constant liaison with his counterparts at the CSIR, who are also currently working on off-road (Dakar) parts.

“In all of this, laser technology was the best option compared to traditional cladding,” notes Haddad. “Together with the CSIR, I believe we will continue to find good solutions to our technical problems going forward,” he concludes.

– Mzimasi Gckumana



Filipe Pereira

An advanced future for **heavy commercial vehicles**

Advanced manufacturing processes in various formats will be shaping the future of heavy commercial vehicles and hopefully, along with it, a more sustainable future.

ALONG WITH THE DEMAND for more goods and services goes the demand for more transport. There is no question that both these needs will be increasing quite rapidly in the immediate future. But our current supply of fossil fuel energy, which is presently the lifeblood of the transport, and specifically the heavy commercial vehicle industry, is not sustainable over the long term. Sixty percent of the almost three billion tons of crude oil that is used annually is in the transport sector.

Climate change pressure is another factor that is pushing the transport industry to implement changes. World opinion is converging towards a reduction of CO_2 emissions, and targets are being set to reduce emissions by 50% by 2020. Every year, the transport sector emits around 5 700 million tons of CO_2. The release of these enormous quantities of CO_2 has been a strong motivator for the introduction of alternative fuels for vehicles, and low regulated emissions are steadily being enforced.

Advanced control systems

The heavy commercial vehicle industry, in attempting to change and help ensure a more sustainable future, is turning to advanced manufacturing processes and technologies. Among others, advanced control systems are being considered and are steadily being used in order to be able to monitor and control the lean efficiency of internal combustion engines (both those in use and those still under development) to meet the more stringent requirements of low emission heavy vehicles. These are especially relevant where the mix of alternative fuels and hybrid powertrains are introduced.

Future control systems will depend on and require sophisticated sensors and micro-actuators for their input signals and fast output control responses. Here, two CSIR research competences, namely, mechatronics and micromanufacturing, as well as sensor science and technology, are well positioned to contribute to these current and future requirements.

Alternative fuels

Several more sustainable and green processes and technologies to produce alternative fuels also fall under the advanced manufacturing umbrella. Some of the fuels currently being considered include ethanol, methanol, diesel (conventional and synthetic), rapeseed methyl ester, dimethylether, methane (which is produced in nature) and hydrogen.

Within the CSIR, researchers in energy and processes as well as metals and metal processes are working on lithium ion (Li ion) batteries and hydrogen fuel cells. The Li ion battery is considered the most viable power storage alternative in any serious attempt aimed at the introduction of hybrid power transmission solutions currently under consideration and development for heavy commercial vehicles.

Another alternative to consider is to reduce or even cut out the industry's dependence on fuel completely. Hybrid powertrains are being envisaged where battery packs, combined with electric motors, will be used for short trips. For longer trips, systems for regenerative brake power and the continuous charging of batteries are being investigated. Advanced manufacturing features as a critical component of the development of these technologies.

Lighter vehicles

Looking at advanced ways to power heavy commercial vehicles is only one side of the coin. Another area that can be significantly improved upon is the actual weight of the vehicles. Weight reduction in order to attain improved fuel efficiency is being sought through the replacement of the materials that automotive parts are manufactured from. Biocomposite materials, made from natural products, can both be strong and lightweight. They are viable replacements for many automotive parts, especially in the interior of the vehicles. CSIR research on fibres and textiles, as well as polymers and composites are capable of responding to these future demands, if required.

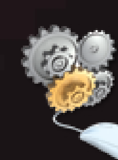
It is anticipated that, in the not-too-distant future, heavy vehicles will experience a tenfold increase in the use of aluminium castings to replace parts currently being made of steel. This will have a significant impact on the weight of the vehicles and therefore their fuel efficiency. The CSIR, through its research in semi-solid metal casting and its patented rheocasting technology, already has the proven technology base to assist industry with this conversion.

Go local

One should keep in mind that most of South Africa's heavy vehicles are imported or assembled by the big-name manufacturers (original equipment manufacturers, or OEMs). For them to expand their market share, it could be wise to use South Africa's emerging market with its local engineering, sourcing, production and sales expertise.

For South Africa to be able to benefit from future advanced manufacturing solutions for heavy vehicles, it is imperative that all stakeholders, including government, research and education institutions, support local industry in their endeavours to capitalise on the needs of the OEMs as well as develop our local OEMs to grow with the domestic and global markets.

– Filipe Pereira



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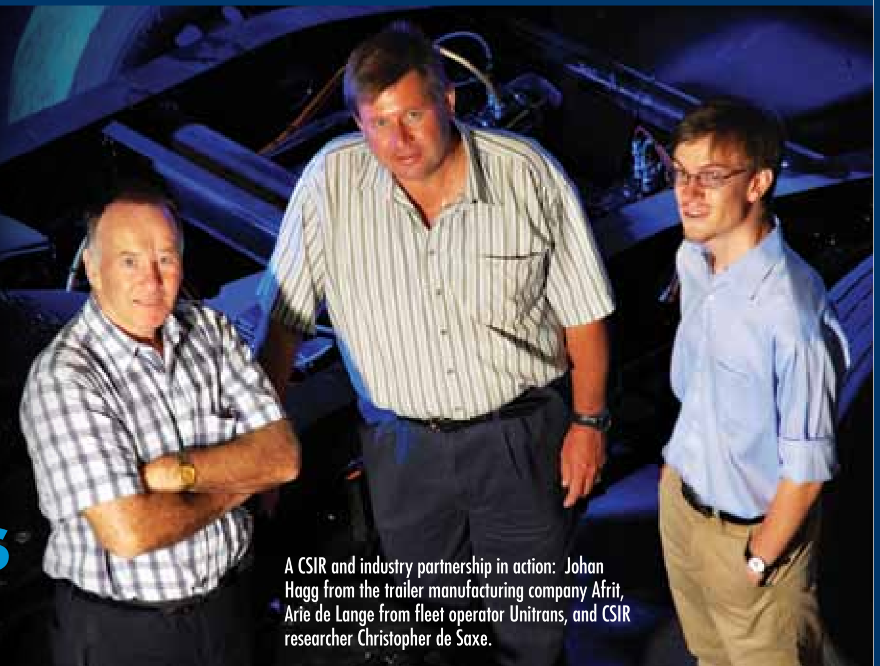
Trailers designed and manufactured locally for **Smart Trucks**



A CSIR and industry partnership in action: Johan Hagg from the trailer manufacturing company Afrit, Arie de Lange from fleet operator Unitrans, and CSIR researcher Christopher de Saxe.

Heavy vehicle designers can now use innovative solutions and the latest technology to meet required performance standards with improved safety outcomes and productivity, while resulting in the more effective use of local road infrastructure.

THE PERFORMANCE-BASED STANDARDS (PBS) approach, adapted for local conditions and recommended by the CSIR for heavy vehicles, has been taken up by various companies as part of the 'Smart Trucks' research programme. The trailers of Smart Trucks, which conform to PBS, are being manufactured locally, according to preapproved specifications and routes.

"Proposed Smart Trucks have to undergo a comprehensive approval process and meet regulatory requirements before the trailers are manufactured," notes local PBS expert, Paul Nordengen of the CSIR.

The concept design of a Smart Truck must indicate key dimensions, axle unit masses and the tyre sizes. The design standards for the trailers include high- and low-speed directional and non-directional manoeuvres in which standards such as tail swing, low-speed swept path, static rollover threshold, rearward amplification, yaw damping and high-speed transient off-tracking are assessed.

"Principle approval is also required from the provincial departments and national Department of Transport, according to the Abnormal Load process. The final assessment reports together with the final vehicle design and proposed routes must then be submitted to the Smart Trucks Review Panel for approval," explains Nordengen, who chairs the review panel.

Only once the final operational approval is received, may the applicant proceed to buy vehicle components and manufacture the trailer according to the approved design and specifications.

Design

Required vehicle design features include:

- ABS/EBS braking systems
- Retarders/intarders
- Side marker lights (truck tractor – 'horse' and trailer)
- Abnormal load signs on the front and back of the vehicle
- A vehicle management system for monitoring the driver's performance, including speeding, harsh braking or acceleration and vehicle location.

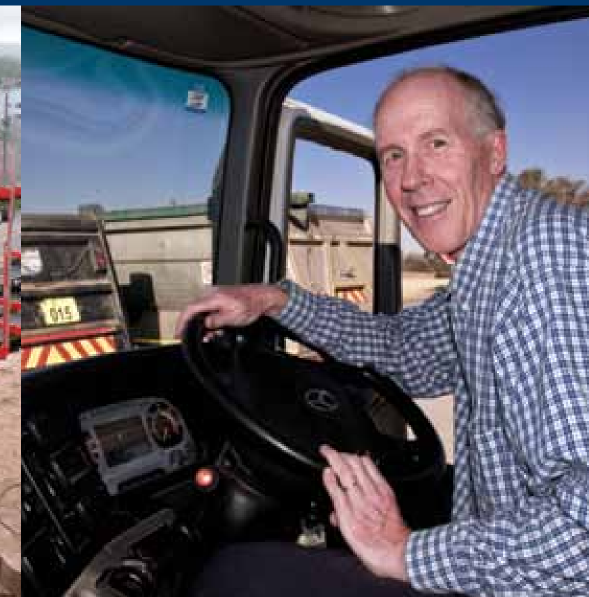
Fleet operators

Smart Truck demonstration projects are being used in the forestry and mining sectors, with a number of other projects in the design phase representing various industry sectors.

"As a fleet operator, Unitrans chooses the horse, or truck tractor, from existing suppliers according to the loads our trucks have to be able to pull. Our trailer design and manufacturing partner is Afrit," says Arie de Lange, Unitrans technical manager for agriculture and mining services.

"Unitrans decided to go the Smart Truck route as it cuts down on the number of vehicles.

Truck trailers manufactured according to performance-based standards.



CSIR expert Paul Nordengen who chairs the Smart Trucks Review Panel.

A heavy vehicle that conforms to the requirements as set out in the 'Smart Truck' research programme.

The risk is thus reduced in terms of the number of accidents occurring, while accident levels are also down due to all our vehicles on the road having to comply with safety standards as set out in the PBS. The Smart Truck definitely leads to increased productivity. We can, for example, move more tons of cargo per kilometre with these trucks," notes De Lange. A reduction in emissions per ton of cargo transported is another positive spin-off.

"The CSIR also undertakes road wear analyses of our trucks to inform us which kinds of tyres cause the least damage of the roads we are permitted to use," he comments.

The fleets of participating operators of Smart Trucks are accredited through the Road Transport Management System self-regulation programme. The PBS approach thus allows for a good 'match' between a vehicle and the subset of the road network it will use, ensuring protection of the road infrastructure and adherence to acceptable safety standards.

"We receive operational data of the Smart Trucks on a monthly basis to monitor compliance, and to evaluate the benefits of the PBS research programme demonstration projects," notes Nordengen.

Trailer manufacturing

"In collaboration with the client, we design the PBS trailers within the length and height specified and according to the needs of the client, in this case Unitrans," says Johan Hagg, sales executive of trailer manufacturer Afrit.

"It is a very thorough, and thus long, process to get approval for manufacturing a Smart Truck trailer. This is to ensure that all safety requirements and PBS specifications are met. From the start of the initial paperwork to getting the go-ahead for production in the factory, usually takes up to three years," Hagg notes.

"Logistics service providers have expressed a growing need for Smart Trucks as they realise they will need fewer vehicles with the longer trailers," he says. The longest truck-trailer combination to have been built at Afrit was 43 m, for use in the mining sector.

Human capital development

Christopher de Saxe of the CSIR conducts research within Nordengen's group on the possibilities of PBS for car-carrier trucks. As part of its human capital development drive, the CSIR enables De Saxe to complete his MSc in engineering through a studentship at the University of the Witwatersrand (Wits).

"Wits and the CSIR have been contracted to perform PBS assessments of proposed car-carrier designs," says De Saxe. Initial analyses of low-speed manoeuvrability have shown that a large percentage of the existing South African fleet fails to meet the requirements of the 'tail swing' standard. Tail swing is the amount by which the rearmost outer corner of a vehicle or trailer swings outwards during a low-speed turn.

"To date, two car-carrier designs have undergone detailed assessments and have been modified to address the tail swing problem. The design modifications have resulted in improvements in other safety-critical aspects of the vehicles. This is a good example of PBS at work in improving overall vehicle safety," concludes De Saxe.

– Hilda van Rooyen

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Performance of tyres, heavy vehicles and roads to be improved through **stress-in-motion technology**

Manufacturers of tyres and road-surfacing materials can improve the performance of their products when using design recommendations following CSIR research and development (R&D) on the actual contact stresses between tyres and the road surface.

THE CSIR, in collaboration with industry and academia, has developed unique stress-in-motion (SIM) technology and devices to measure and quantify the effects of the multi-dimensional stress on both tyres and roads. The stresses or forces, resulting from the contact between a moving tyre of a heavy vehicle and the road it travels on, are telling in terms of the performance of both the tyre and the road.

"The SIM device was developed mainly for the measurement of slow-moving, full-scale pneumatic truck tyres at a speed of approximately 5 km/h. Our SIM measurements provide rational descriptions of multi-dimensional tyre and road contact stresses in the vertical, lateral and longitudinal directions that can be used for tyre and road design, testing and evaluation," explains Dr Morris de Beer from the CSIR.

Measurement options include dynamic, moving measurements of single and twin-tyre, or full vehicle configurations, varying pneumatic and solid rubber and tyre sizes relating to optimal-designed width and associated diameters.

"Our research using SIM technology has proved that significant unequal load sharing is experienced between the individual tyres and also the axles of heavy vehicles. This leads to uneven deformation of the tyres as well as the road surface. These results disprove previous assumptions in tyre and road design that equal weight is shared between the various tyres and axle groups for a given heavy vehicle," De Beer notes. In February 2012, he presented these and other findings at the 14th annual Tyre EXPO and Conference in Cologne, Germany.

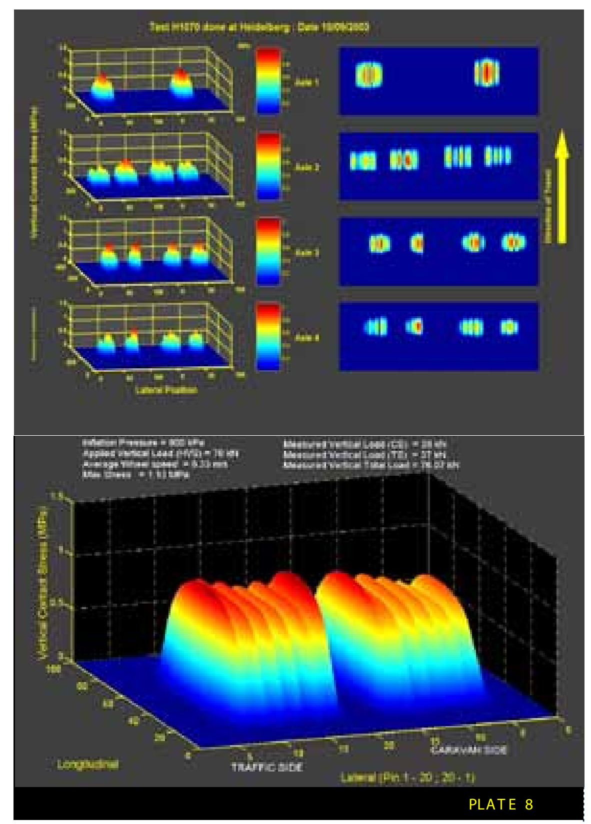
"The vehicle, suspension, tyre and road surface should be viewed holistically. That is why tyre, vehicle and road engineers should have a closer working relationship, something that is not the norm in our industry. This view is shared by my peers in the UK, the USA, Germany and China," adds De Beer.

Typically, a pneumatic rubber tyre consists of the tread with sidewalls and bead bundles, cap plies, steel belts, body plies and an inner liner. Inflation pressures of tyres increase with temperature over running time and, in addition, there is not always a constant uniform contact stress of circular shape between different tyres and the surface of the road. These depend heavily on the tyre design, tyre loading and its inflation pressure.

South Africa has a total road network of some 750 000 km, which includes freeways and national roads, main, secondary and tertiary provincial roads. Of the rural network, about 20 to 30% is 'paved', be it with 'black top' or asphalt all-weather road-surfacing layers. The impact of tyre–road contact stresses has a direct effect on the deterioration of tyres, vehicle suspension systems and roads.

In a CSIR study commissioned by the South African National Roads Agency Ltd, a selection of real-time heavy vehicle traffic was diverted over a quad SIM system at a speed of 5 km/h. The test series lasted for a period of six weeks, testing a total of close to 3 000 heavy vehicles that represent a unique data set of tyres.

The CSIR's Dr Morris de Beer has played a key role in the stress-in-motion (SIM) technology.



The typical vertical tyre-road contact stresses of a four-axle vehicle (top), and from a set of dual truck tyres (bottom) as measured with the SIM system.

"Traditionally, tyre and road designers assume that the vertical contact stress between the tyre and road is equal to the tyre inflation pressure, and that it is distributed evenly on a circular area. Several studies have shown an increase in the inflation pressure of the tyres of heavy vehicles, with data showing an increase of 30 to 70% in average inflation pressure over a period of 30 years," says De Beer.

Another CSIR study, commissioned by the Gauteng Department of Transport and Public Works, showed an increase in average inflation pressure when the tyre was cold, from 633 kPa in 1974 to 733 kPa in 1995. Current inflation pressures are approaching an average of 800 kPa, and typically 900 kPa on steering axle tyres, with maximum pressures exceeding 1 100 kPa.

The SIM equipment of the CSIR was used to evaluate and footprint tyres for special landmine detonation trailers as well as low-pressure (flotation) tyres. These tests provided critical information for the improvement of tyre design for Protected Mobility, a division of DCD (Pty) Ltd that manufactures and supplies this equipment internationally.

"During the 1990s the so-called 'super single' wide-base tyres were evaluated for clients, including some in the USA (the states of Texas and California) and The Netherlands," De Beer explains.

The CSIR research results can be used to improve the design and performance of tyres, truck and trailer suspension design and the performance of construction materials, and the methodology of road construction. "The CSIR has built up expertise on tyre and road interactions with more than 57 000 truck tyre measurements. In future, our advanced R&D using SIM will potentially allow for high-resolution road contact stress measurements such as from passenger car tyres, requiring a holistic approach with due cognisance of global trends," concludes De Beer.

– Hilda van Rooyen

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The total South African tyre market comprises about 250 000 tons of new tyres annually, of which more than 60% is produced locally. Four local tyre manufacturing companies have a proven track record and South Africa has an active retread industry, specifically in the heavy vehicle tyre sector. This is according to the South African Tyre Manufacturers Conference and the South African Tyre Recycling Process Company. The latter is a non-profit organisation established by producers (manufacturers, importers and retreaders) in the tyre and motor industries for them to take up their producer responsibility in terms of the Waste Tyre Regulation, 2009.

Semi-solid cast engine-mounting bracket

Shifting boundaries in semi-solid metal casting

Dr Hein Möller – "The challenge is to cast alloys to a near-net shape and achieve mechanical properties similar to wrought material."

Dr Sagren Govender – "We are focusing on the material properties of difficult-to-cast wrought aluminium alloys."

Ulyate Curle – "We hope to help create a database on the properties of wrought aluminium alloys."

The CSIR's patented semi-solid metal casting technology proves its mettle

It was once a well-published fact that pure metals and eutectic alloys could not be cast using a semi-solid metal (SSM) casting process. When researchers at the CSIR did it with high-purity aluminium and the Al-12Si eutectic alloy, using their patented SSM Rheocasting system, they shifted boundaries.

BY DEMONSTRATING THE FEASIBILITY to cast pure aluminium, eutectic aluminium–silicon alloys and a variety of casting and wrought aluminium, as well as magnesium alloys, CSIR researchers proved that the CSIR Rheocasting system is both flexible and capable of processing just about any alloy/metal with a melting temperature below 1 000 °C.

Dr Sagren Govender, research group leader of the advanced casting technologies group at the CSIR, says that they hope this achievement will allay some of the negative impressions industry seems to have about SSM casting.

"The world over, industry has been slow to embrace SSM casting," he explains. "This is mainly due to problems experienced with consistency, which led to cost increases. What we have found is that it is not the technology itself or to put it more simply, the process to get the metal to a semi-solid state, that holds the key. It is an entire system that has to be looked at."

The system includes several components, including the Rheocasting system integrated in a high-pressure die-casting cell, the die-design and post-processing steps to achieve the required material properties.

"We have spent the past couple of years fine-tuning and optimising the system. It involved sorting out several technical niggles with every component in this system. Now we are mostly focusing our research efforts on the material properties of high-strength, heat-treatable, difficult-to-cast wrought aluminium alloys."

Senior researcher, Dr Hein Möller, explains that wrought alloys are difficult to cast using conventional liquid casting techniques. However, SSM technology allows this to be done. "It is extremely difficult to cast a part with wrought alloys to near-net shape. Getting a part cast into a near-net shape means that the part will require very little machining in order to have its final, usable shape. That way you save money because there is very little waste."

He says that while it is possible to do so with SSM technology, internationally the challenge now is to achieve mechanical properties similar to wrought material.

"You start off by choosing an alloy that has the properties you need to suit the end-product. This can be achieved by a suitable heat treatment of the casting," he explains.

Fellow senior engineer, Ulyate Curle explains that a large part of this challenge lies with the fact that there is no current full database for mechanical, tensile, corrosion or fatigue properties of especially wrought aluminium alloys when using SSM processing. "We hope that with our work we will be making a contribution to getting such a database established," he adds.

According to Govender, while the industrial uptake of SSM technology seems to have taken a knock on the back of the negative perceptions out there, the interest in its abilities as a cost-saving tool remains. The CSIR will be hosting the 12th International Conference on Semi-Solid Processing of Alloys and Composites in Cape Town from 9 to 11 October this year. The plenary speakers will mostly be from industry, (and not only from the research environment), to stimulate discussion on the industrial applications of SSM technology.

"Because of our active participation in semi-solid processing and this international conference series for the past 10 years, we were offered the opportunity to host the conference. We have received over 130 abstracts for the conference," concludes Govender.

– Petro Lowies

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Forging ahead
to a titanium metal industry

Dr Willie du Preez, CSIR metals and metals processes manager and convener of the Titanium Centre of Competence

Over the past decade, there has been a growing realisation in South Africa that the country had an industrial opportunity to add much more value to its vast resources of titanium-bearing minerals. Cost-effective local production of titanium metal and the conversion of titanium alloys into products, offer the potential of a vibrant new South African industry sector.

SOUTH AFRICA is currently the world's second largest producer of raw titanium minerals after Australia, yet the country has a very limited market position in the production of TiO_2 pigment and no position downstream in the value chain for the production of primary titanium metal, mill products (large basic shapes such as plate, bar, tube, etc.) or finished components.

In 1999, a foresight study, commissioned by the then Department of Arts, Culture, Science and Technology, recommended government support for research and development (R&D) on titanium and titanium oxide production from local raw materials. Following the publication in 2002 of the Department of Trade and Industry's Integrated Manufacturing Strategy and the Department of Science and Technology (DST)'s National R&D Strategy, the Advanced Manufacturing Technology Strategy was developed as the implementation strategy, and accepted in 2003 by the South African government. The Advanced Metals Initiative was established in 2005, with the Light Metals Development Network (LMDN), led by the CSIR, as one of its focus areas. The LMDN has since focused on titanium and aluminium.

Soon the national support for R&D on titanium grew, particularly due to significant opportunities in the aerospace sector, such as Boeing's interest in South Africa as a potential future supplier of titanium alloys.

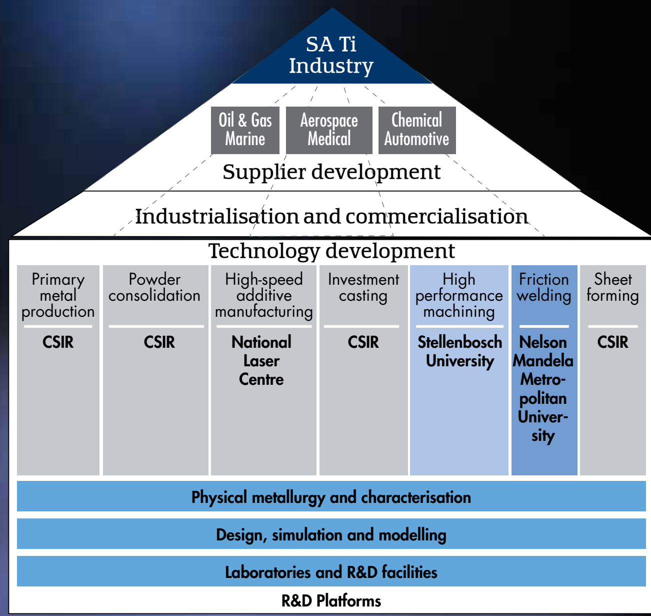
Given its strong position with regard to the mining of the titanium bearing minerals, ilmenite and rutile, and the growing markets for titanium, South Africa has an opportunity to develop a metal industry. Key to this is a technology, developed by CSIR researchers, for extracting the pure titanium from the mineral more cost-effectively than the current commercial process for titanium production. A feasibility study, commissioned by the DST and published in 2008 provided sufficient confidence for a national titanium industry strategy to be launched.

As the vehicle to establish the technology building blocks of such an industry, the Titanium Centre of Competence (TiCoC), led by the CSIR, was conceptualised.

The mission of the TiCoC is to develop and commercialise the technology building blocks needed for a new South African titanium metal industry. A number of national R&D platforms have been aligned to support the technology development. The CSIR, various universities, science councils, R&D institutions and private companies are collaborating in developing the technology building blocks and R&D platforms, as indicated in the TiCoC diagram.

South Africa is poised to become a player of note in the international titanium arena. Significant progress has been made over the past six years with the development of the technology building blocks for the future South African titanium industry. Serious commitment to realising the vision of a local titanium industry by 2020 is being demonstrated by the South African government and the R&D community.

– Dr Willie du Preez



Titanium Centre of Competence:
Developing and commercialising technology building blocks for the South African titanium industry

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Piloting a titanium metal production process

Titanium powder produced with a CSIR process. Examples of products made with the powder are also displayed: The part in the very front through additive manufacturing and the other two through powder metallurgy processes.

To date, no organisation in the world has been able to produce titanium powder directly in a continuous manner on a commercial scale from titanium tetrachloride ($TiCl_4$ – the usual precursor used for titanium metal production). The CSIR has developed a process that can do just this, and will be setting up a pilot plant in the near future.

FOLLOWING AUSTRALIA, South Africa is endowed with the second largest (about 16%) of titanium-bearing reserves in the world. In South Africa, the mineral is mined and then concentrated to form slag. This is exported as a relatively low-value commodity, meeting about 20% of the world's current raw material demand for titanium dioxide pigment, and titanium metal production.

> *"The national benefits that would arise from a world-scale, low-cost titanium metal plant are considerable."*

The potential to add more value to the raw material through the establishment of titanium pigment and/or metal industries had been identified in a number of South African government studies (dating back more than 15 years) and featured in a number of national strategies.

Why SA needs a titanium metal producing plant

The national benefits that would arise from a world-scale (20 000 tons per annum), low-cost (about US$20/kg milled products at 50% of the current price) titanium metal plant are considerable, with the most important being:

- Revenue of about US$400 million per annum from the milled product plant alone can be forecast. Revenue could increase to almost US$1 000 million per annum once a downstream industry for the production of semi-finished products has been fully developed.
- Establishing an industry will lead to many downstream manufacturing enterprises that would not be possible without such a local industry.
- There is potential for the creation of about 1 500 permanent jobs once the downstream industry has been developed to a point where semi-finished products are produced. This number could increase with more final products.
- These industries would potentially create opportunities for the establishment of small and medium enterprises and complement Black Economic Empowerment.
- Support industries could be developed that will further assist with the expansion of the South African economy through job creation and revenue generation.
- A large part of South Africa's annual importation of about 800 tons of titanium in various forms (sponge, scrap, ferrotitanium, etc.) can be replaced, saving about US$5 million per annum in foreign exchange.

In order to realise the opportunity to establish a titanium metal industry in South Africa, a focused programme to achieve such an objective was formulated in 2007 by the Department of Science and Technology (DST) together with the CSIR and the research and development community.

A novel process to produce titanium metal powder

A key element of the programme is the development of a novel process to produce titanium metal powder that will give a competitive advantage to the envisaged local titanium metal industry. This process is being developed by the CSIR in a stage-wise manner to manage the inherent scale-up risks, and it has now reached the stage where the design, construction and operation of a small pilot plant have been approved by the DST and the CSIR.

The pilot plant has a nominal design capacity of producing 2 kg/h of titanium powder continuously. Construction and commissioning of the plant are to be completed by 31 March 2013. Test campaigns to gain scale-up information regarding the process, and to produce sufficient product for evaluation by potential customers, are planned following successful commissioning of the plant.

Similar to the CSIR, a number of organisations worldwide are busy scaling up their own variations of processes to produce titanium metal powder. Problems with the process include the very high heat of reaction, the very fast rate of reaction, the aggressive and hazardous nature of the chemicals involved, and the tendency of the titanium product to form lumps that block the reactor inlets and outlets.

In the CSIR's process, the rate of $TiCl_4$ reaction is slowed down by executing the process in a molten salt medium that allows better control of the titanium particle morphology than other process variations.

In parallel to the technical work, a commercialisation task team with representation from industrial and financial concerns has been formed to plan and manage work to ultimately realise commercial implementation of the strategy.

South Africa's entire titanium beneficiation strategy depends largely on the success of this pilot plant and its further commercialisation. Being able to produce titanium powder at a much lower cost than present imports will make this light metal an economically viable option, from which many industries can be created and sustained.

– Dawie van Vuuren

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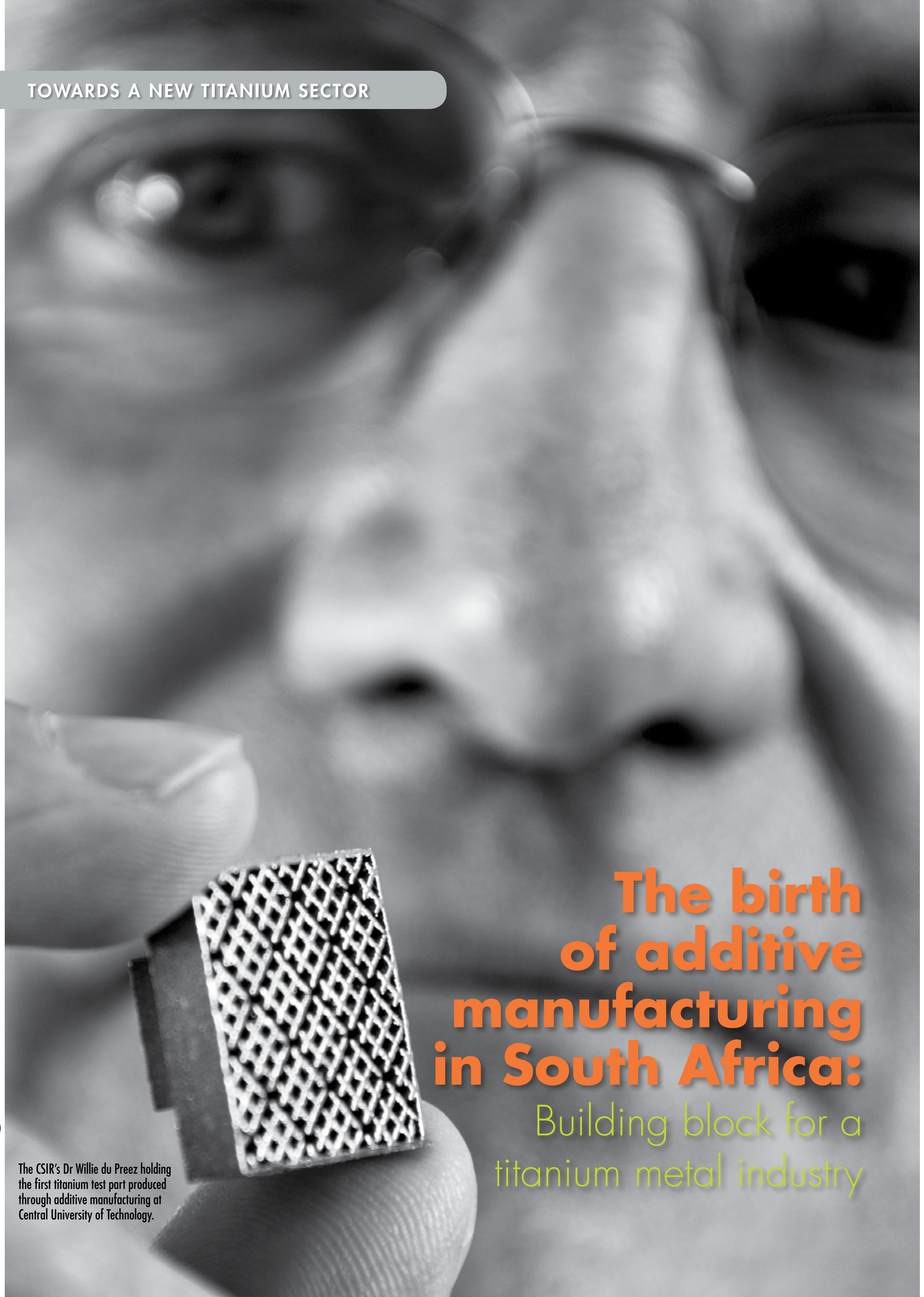
Dr Dawie van Vuuren heads up the CSIR's piloting of titanium metal production.



The CSIR's Dr Willie du Preez holding the first titanium test part produced through additive manufacturing at Central University of Technology.

The birth of additive manufacturing in South Africa:

Building block for a titanium metal industry

Guests viewed the various laser facilities at the launch of the additive manufacturing platform at the CSIR National Laser Centre. Deputy Minister of Science and Technology, Derek Hanekom said that the launch was a milestone for the attainment of the objectives of two key initiatives of the Department of Science and Technology namely, the Advanced Manufacturing Technology Strategy and the Advanced Metals Initiative.

Additive manufacturing used to be called rapid prototyping and, in the early 1990s, there were only three rapid prototyping machines in the country. These machines could only manufacture plastic or resin-type prototype parts. Today, there are 434 additive manufacturing machines in South Africa and at least two of them are capable of manufacturing parts made from titanium.

THE MANUFACTURING technology called additive manufacturing has almost taken on a life of its own. It is actively being used by part-manufacturing industries in South Africa, and the CSIR in collaboration with Aerosud is developing technology that will push it into the sphere of manufacturing large titanium parts. Along with the local manufacture of titanium powder, this technology is one of the building blocks in establishing a titanium metal industry in South Africa.

South Africa's additive manufacturing story began in the early 1990s when there were only three rapid prototyping machines in the country. Dr Willie du Preez, who heads up the CSIR's metals and metals processes area, recalls that two of these machines belonged to the CSIR, and one was owned by a private company.

"The CSIR played a leading role in introducing the technology to industry," he reveals. "We bought a large stereo-lithography machine in 1996 that could produce parts in a polymeric resin. Soon after this, the technology started to use metal powders mixed with the resin to manufacture parts. Rapid prototyping technology was also an offering of the National Product Development Centre that was hosted on the CSIR's Pretoria campus," he says.

Two years prior to the purchase of that machine, Prof Deon de Beer from (what is now known as) Central University of Technology (CUT), spent his sabbatical at the CSIR and was introduced to rapid prototyping. "He became a true champion for this technology," says Du Preez. "When he went back to CUT he started up a department that focused specifically on rapid prototyping. This soon resulted in a national Centre for Rapid Prototyping and Manufacturing at CUT."

From the beginning, there has always been close collaboration between CUT and the CSIR in this field. They worked together to promote the technology among industry players. The technology also evolved to move from metal polymer mixes to only metals.

Du Preez continues: "In more recent years the technology has moved from being a prototyping tool to a manufacturing tool. Internationally, the name changed along with it. Rapid prototyping became additive manufacturing."

In 2007, CUT commissioned one of the very first additive manufacturing machines in the world, capable of producing parts in titanium. In the bigger picture of the Titanium Centre of Competence, a network of researchers, industry players and government departments aim to establish a titanium industry in South Africa, and this has become one of the building blocks for a fully fledged titanium industry.

"The CSIR collaborates closely with CUT on the characterisation of the titanium parts that it manufactures," says Du Preez. He explains: "Characterisation involves evaluating whether the metal of the part complies with the right standards and specifications. It is a crucial step should one want to qualify your manufactured parts for the aerospace or medical implant industries."

Over the last year or so Vaal University of Technology (VUT), again under the leadership of Prof De Beer, also started to collaborate on the characterisation of titanium metal in the additive manufacturing of titanium parts.

Says Du Preez: "Since the early 2000s, industry started to take up the technology and at last count at the end of 2011, there were 434 additive manufacturing machines in the country. Their capabilities are mostly in plastics and some metal part manufacturing, but two of them can produce in titanium. The CSIR, together with Aerosud, CUT and VUT, are moving ahead with introducing titanium additive manufacturing as a leading future technology."

He adds that both CUT and VUT are playing a vital role in the training of students for the additive manufacturing industry. "It's another essential cog in the process of establishing a viable industry for the technology and, especially, titanium."

Also read article on page 12.

– Petro Lowies

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Producing titanium castings:
A new South African opportunity

The few companies around the world that produce titanium castings using an investment casting process keep their cards close to their chests. For this reason South Africa had to develop its own process, while ensuring that it is both cost-effective and commercially viable.

CSIR technical assistant Sam Papo removing casting moulds from the wax melting oven.

The CSIR's investment casting team. From left are Sam Papo, Nonjababuiliso Mazibuko, Pierre Rossouw, Peter Malesa and William Tefu.

A wax mould of an aircraft part. A face coat as well as a refractory stucco, followed by layers of back-up refractory coats, will cover the final wax assembly. It will be dried completely before the wax can be removed from the formed shell, into which titanium will be cast.

THE INVESTMENT CASTING of titanium is one of the technology building blocks that South Africa needs in its strategy to develop an entire titanium value chain for a new industry sector. With investment casting, it is possible to cast parts with intricate shapes and thin walls into a near-net shape, meaning that the parts will not need expensive and difficult machining after the casting process.

"Because of the metal's highly reactive nature, the investment casting of titanium is a great deal more intricate than the usual investment casting process," says Pierre Rossouw, principal technologist with the CSIR's metals and metals processes group. "Also, very little has been published about the process, as the companies that are able to do it prefer to keep this as proprietary information."

Rossouw's job is to see if CSIR-produced titanium powder can be used in a casting process for industrial components. The CSIR's goal with the investment casting of titanium is not only to do castings, but to optimise every step in the process so that the technology, equipment and everything needed for the process, can be successfully transferred to industry.

The team started by identifying and then mastering each of four critical technologies needed for the process. The first was the face coat, the first layer of the investment mould that reduces the reaction between the titanium and the mould material during the casting process. There is always an oxygen-rich reaction layer after casting, referred to as an alpha case. The second stage involved the development of intricate melting techniques. This was followed by the chemical milling process to remove the alpha case that formed due to the limited reaction with the face coat during casting. Lastly, a technique called HIPing (Hot Isostatic Pressing) had to be mastered, which closes and fuses any internal micro-porosity the cast component might have.

The market for titanium lies mainly with aerospace, medical, oil and gas, power generation, high-end automotive, sport and jewellery industries. The demand for it is growing rapidly, both internationally and locally.

Rossouw explains that each of these techniques had to be optimised, with cost savings for industry always top of mind. He also had to look at the mechanical properties of the castings, where especially fracture toughness and fatigue resistance proved to be the most important requirement for clients.

While the CSIR has now developed the capacity to commercially cast titanium parts, the organisation is still continuing with research and the transfer of the technology. The overall goal is to maintain a development base for the future that can support industry with new techniques and problem solving.

"We plan to be running with the process commercially by 2015, but we are not sure in which format this will be," says Rossouw. "We might be setting up a completely different plant, use the existing one with an industrial partner or look at other ways to implement it. Either way, the plan includes all the infrastructure, human resources development and the technology of the process."

Apart from perfecting and optimising the investment casting process for titanium, the CSIR is also working with the Department of Science and Technology on a three to four-year plan that includes a market evaluation; the technology's industrialisation; a plan for human resources requirements and training; and a commercially viable business plan for its commercialisation.

"I believe that the investment casting of titanium represents a wonderful opportunity for the local manufacturing industry," concludes Rossouw. "The industry will have access to locally produced materials and techniques that previously had to be imported at a very high premium. We have already had some interest in it, and we are working with the international aerospace industry to ensure that we meet its rigorous standards."

– Petro Lowies

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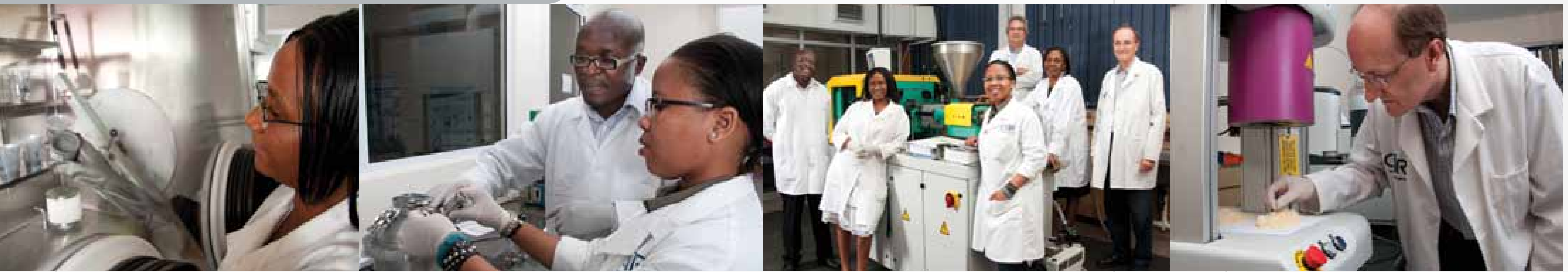
Pierre Rossouw, principal technologist at the CSIR, believes that the investment casting of titanium represents a wonderful opportunity for the local manufacturing industry.

About titanium

- Titanium never occurs in nature as a metal. It is found in mineral form and to get to metal, the mineral must first become titanium oxide or titanium dioxide, after which it can be converted into titanium ore and finally into metal.
- The complex process of converting titanium ore into metal has only been commercially viable for a little more than 50 years.
- The use of titanium has since then expanded by an average of 8% per year.
- The largest deposits of ilmenite sands and rulite (from which titanium is derived) are found in Australia, South Africa and Canada.
- Despite its abundant deposits, South Africa does not have a titanium industry.
- Titanium is stronger than steel but 45% lighter.
- Titanium is 30% more elastic than steel.
- Titanium has an extremely high melting point of 1 660 °C and is cast at temperatures of 1 750 - 1 800 °C.
- Titanium is a very reactive metal. It spontaneously forms a hard, protective oxide film when it comes into contact with oxygen at elevated temperatures. This necessitates all thermal processes to be done under a very good vacuum or protected gas (in the case of lower temperature operations).
- When the process of investment casting is used to manufacture parts from titanium, less of the valuable titanium alloy is wasted. This is because investment casting produces parts in a near-net shape that requires very little and often no machining thereafter. Investment casting is also suitable for the production of parts that have extremely intricate shapes and/or thin walls.



Perfecting processes: The CSIR's powder metallurgies group.

Titanium powder metallurgy: A cost-effective technology crucial for establishing a titanium industry

Manufacturing components with powder metallurgy techniques is one of the crucial technologies for establishing a viable titanium metal industry in South Africa. At the CSIR, researchers are perfecting these processes specifically with this industry in mind.

POWDER METALLURGY is the process of blending fine powdered metals, pressing them into a desired shape (compacting), and then heating the compressed material in a controlled atmosphere to bond the metal particles (sintering). Components can be made to final dimensions or very close to these with little or no subsequent machining operations required. Using metal powders to produce parts using this technique is not uncommon. But doing so using titanium makes everything much more complex.

"This is because titanium is very reactive, and minimising its pick-up of oxygen and carbon is crucial to avoid degrading the mechanical properties of the final part," says Jeff Benson, CSIR researcher. He goes on to explain that the extremely high cost of obtaining titanium powder has also limited its use, and that this has prevented an industry from forming in South Africa.

In support, Dr Hilda Chikwanda, research group leader of the powder metallurgy technologies group, says that even though titanium and titanium alloys have become the preferred materials for many chemical, energy, surgical and aerospace applications, the high cost of titanium components has limited its use.

With CSIR researchers now having developed an alternative, more cost-effective way to produce titanium powder from South Africa's own abundant resources (see article page 28), the final cost of titanium components will be significantly reduced.

"This means that we can use powder metallurgy techniques to make mill products (large basic shapes such as slabs, plates and tubes) as well as final components, and so avoid the conventional and energy-consuming steps of re-melting and casting from solid metal," says Benson.

The CSIR's powder metallurgy technologies team already has the ability and the facilities to produce small titanium components using press and sintering as well as injection moulding techniques. Now the team plans to expand into the development of technologies to make larger shapes, such as mill products. "This will be an essential building block for establishing a competitive titanium industry in South Africa," says Chikwanda.

"Titanium and titanium alloys are popular because of their unique combinations of low density, good mechanical properties, excellent corrosion resistance and biocompatibility."

Benson is positive that the local market for the manufacturing of titanium products will expand considerably once it can be demonstrated that components can, in fact, be produced at significantly lower prices than is currently the case. "Titanium is the metal of choice for a multitude of engineering applications. At its current pricing, however, it is just too expensive for more general use," he states.

The market is very diverse: From aerospace, military and marine applications to off-shore drilling rigs, medical implants, chemical plants, sports equipment, Formula One racing, jewellery, architectural cladding and art.

– Petro Lowies

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The powder metallurgy process generally consists of four basic steps: Powder manufacture, powder blending, compacting and sintering.

Dr Hilda Chikwanda

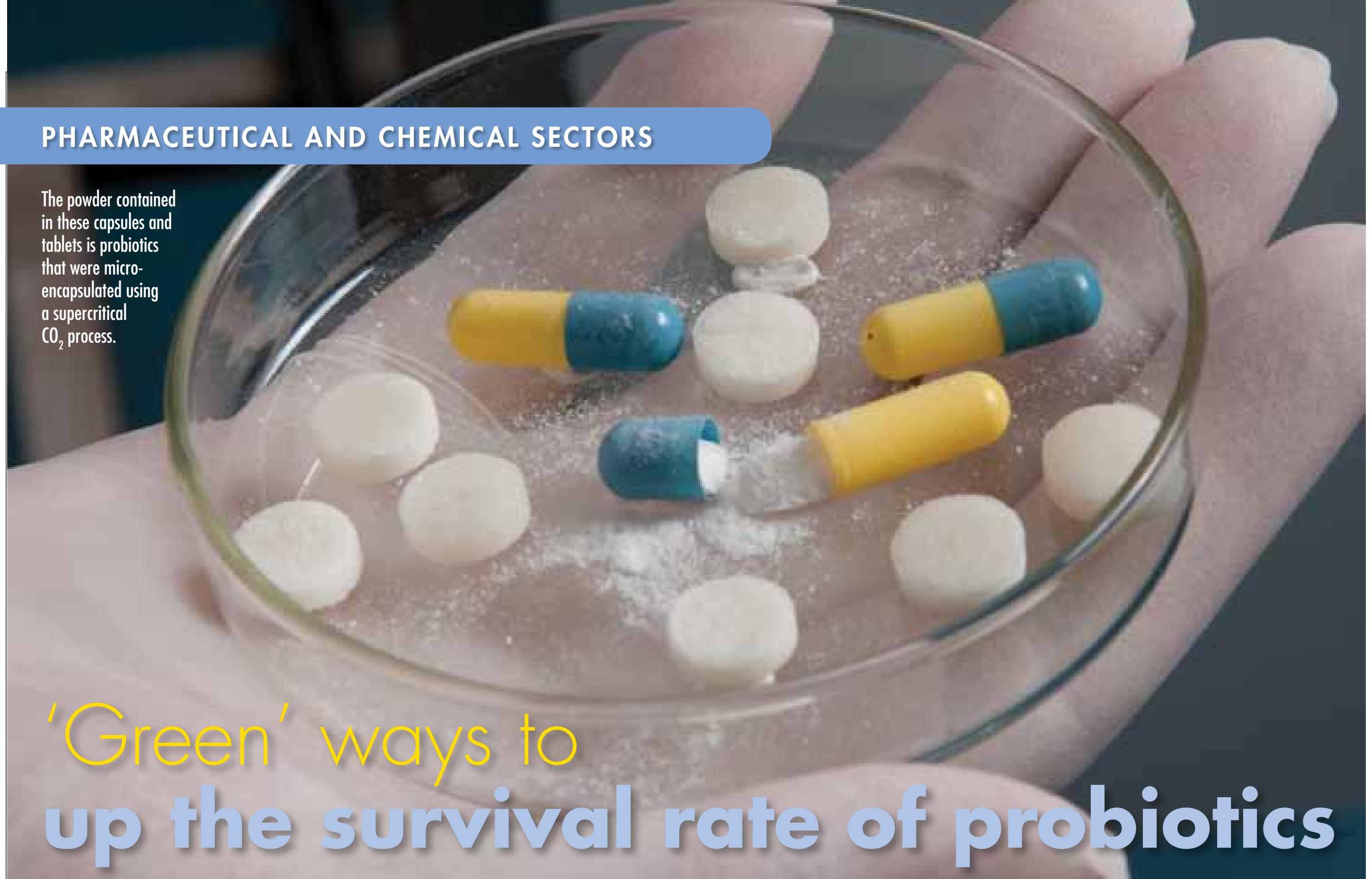
The two approaches of titanium powder metallurgy

Titanium powder metallurgy is generally divided into two approaches, the elemental approach and the pre-alloyed approach.

With the elemental approach, the small grains of titanium (commonly called 'sponge fines'), are used as a starting stock. Alloy additions, normally in the form of a powdered master alloy, are added to these fines, so that the desired bulk chemistry is achieved. The blended mixture is then compacted cold to a desired density. This operation can be carried out either isostatically or with a relatively simple mechanical press. The compact is then sintered to increase the density and to homogenise the chemistry.

With the starting stock for the production of net-shape components by the pre-alloyed approach, the small grains (powder metallurgy particles) already contain the desired alloy components.

Consolidation of both the pre-alloyed powder and the elemental powder may be accomplished using various procedures known in powder metallurgy.



The powder contained in these capsules and tablets is probiotics that were micro-encapsulated using a supercritical CO_2 process.

'Green' ways to up the survival rate of probiotics

A study[1] found that the survival rate of probiotics in, for instance, probiotic supplements, is generally extremely low. These micro-organisms simply cannot withstand the storage process. Is there a way to help them survive and to do so in an environmentally friendly way?

ACTIVE PHARMACEUTICAL INGREDIENTS (APIs) such as probiotics are, in general, very sensitive to high temperatures and solvents. Conventional micro-encapsulation methods are therefore unsuitable to use for APIs, as they typically require high temperatures and/or solvents during the encapsulation process.

"One would encapsulate an API to protect it against elements such as moisture or light in its environment; from gastric acids that can destroy it and also to allow for its controlled delivery in the intestines," explains Dr Philip Labuschagne, a researcher at the CSIR's encapsulation and delivery research group.

Labuschagne has been working on a way to safely encapsulate sensitive actives, particularly probiotics, using a new 'green' processing method. This method entails the use of supercritical carbon dioxide (CO_2) as a process medium.

"The supercritical CO_2 process occurs at mild temperatures (not more than 40 °C) and is non-toxic. In addition, unlike conventional solvents, the CO_2 can be completely removed simply by depressurisation so that the end-product contains no traces of it," explains Labuschagne.

He used this process to develop a polymer matrix that is based on inter-polymer complexation – a process that mixes two complementary polymers with distinct properties in order to obtain a polymer matrix with unique characteristics. For instance, the inter-polymer complex developed by Labuschagne is pH responsive, which means that it will protect the probiotic from gastric acid attacks and ensure its release in the more alkaline pH-environment of the large intestine. In addition, it protects the probiotics from moisture and oxygen during storage.

The end-product is a powder with particle sizes of between 50 and 500 microns (micro-particles). Any probiotic strain can be encapsulated using this technology, and it can also be used for other APIs – even vitamins and possibly vaccines.

"We have already proved that this encapsulation method shows significant improvement in the shelf life of probiotics, as well as greater protection from gastric acids and improved release in the intestines," says Labuschagne. "This technology has been patented and the results published."

Micro-encapsulation using supercritical CO_2 holds immense promise for the entire API manufacturing industry. The project was originally funded by a co-investment from the Industrial Development Corporation, and a company called Ellipsoid was created through which the commercialisation will take place.

1 An evaluation of nine probiotics available in South Africa, August 2003, E Elliott, K Teversham

– Petro Lowies

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The study found that:
… only five out of nine commercial probiotic products in South Africa contain sufficient levels of organisms to have probiotic potential. One of the main reasons for this is the sensitive nature of these micro-organisms to heat, light and moisture.

Probiotics are live micro-organisms (in most cases, bacteria) that are similar to beneficial micro-organisms found in the human gut. They are also called 'friendly bacteria' or 'good bacteria'. Probiotics are available to consumers mainly in the form of dietary supplements and foods.

An example of inter-polymer complexation: The most common interpolymer complex is between polyacrylic acid and polyvinylpyrrolidone. They are both hydrophilic (attracts water), but once complexed they become hydrophobic (repels water).

Micro-encapsulation, in materials science, is the coating of microscopic particles with another material.

Dr Philip Labuschagne adds the raw materials to the supercritical CO_2 reactor to prepare micro-encapsulated probiotics.

Dr Stoyan Stoychev

Using biologics to transform **the drug marketplace**

Biologic products now provide important therapeutic options for a range of serious clinical conditions. Therapeutic biologics such as genetically engineered recombinant proteins and monoclonal antibodies represent a large portion of newly-approved therapies for conditions such as chronic inflammatory diseases and cancer.

THE CSIR is currently building capacity for large-scale recombinant production of biopharmaceuticals. At present, there are a number of such products at various stages in the development pipeline, including therapeutic peptides such as Exenatide (diabetes treatment), Enfurvitide and Griffithsin (HIV inhibitors) as well as anti-rabies monoclonal antibodies (mAbs).

Production of biologics

Biopharmaceuticals are conventionally produced in sterile fermentation facilities using mammalian cell cultures. A drawback of such systems is that they have a limited production capacity, and setting up such facilities requires a huge capital investment. Biologics may also be produced by using recombinant micro-organisms or plants engineered to express a particular therapeutic peptide, protein, monoclonal antibody as well as vaccine sub-unit. The pharmaceutical industry is now being transformed due to the emergence of biologics (biopharmaceuticals) which offer many advantages over conventional small-molecule drugs. These include higher efficacy, reduced side effects, and the potential to cure disease, compared to treating symptoms.

The size and complexity of biologics, in comparison to small-molecule drugs, have brought a unique set of challenges to manufacturers. Therapeutic peptides, proteins and mAbs have to be scrutinised at primary as well as higher-order (native) conformation. Close attention must also be paid to any modifications induced by the recombinant expression system. In addition, product and process-related substances and impurities can affect both the structure and functioning of biologics. Hence, it is critical to be able to detect dimidiated, isomerised, oxidised forms, or protein aggregates as well as host cell protein, DNA and culture components introduced during cloning, production and purification.

In-depth characterisation of biologics

Under these circumstances, manufacturers have to ensure that their products undergo rigorous characterisation to facilitate transition through discovery into development, eventual commercialisation, and their ultimate intended therapeutic use. Achieving this goal is dependent on the availability of appropriate analytical tools to provide an array of chemical and physical information. Hence, a range of approaches has been developed, optimised and successfully implemented in-house for in-depth characterisation of biologics with a focus on meeting regulatory and commercial specifications in order to shorten time-to-market as well as lower risk during product development stages.

The identity of recombinantly expressed peptides, proteins and mAbs is scrutinised using a combination of proteolytic digestion followed by multi-dimensional liquid chromatography peptide fractionation, directly coupled to tandem mass spectrometry. This workflow yields high-resolution peptide sequencing data that not only permit in-depth characterisation of primary structure, but also allow direct detection of post-translational modifications product as well as process-related impurities. In addition, in-house developed microspheres (ReSyn™) are being used to manufacture immobilised protease micro-reactors for fast and efficient protein digestion that yields high coverage primary structure data.

Cutting-edge ultra-high-pressure liquid chromatography systems

Product purity is monitored using electrophoresisas as well as chromatography-based techniques, with separation based on a range of molecular properties such as size, charge, as well as hydrophobicity. The use of cutting-edge, ultra-high-pressure liquid chromatography systems in combination with columns packed with smaller, sub 2 µm size particles, allows for more efficient as well as f aster separation of molecules of interest.

Since native structure dictates function, the understanding of structure and its interplay with function is essential for developing effective, safe, and cost-effective protein biopharmaceuticals. The native conformation of larger peptides, proteins and mAbs is examined on a global scale using circular dichroism, which monitors changes in secondary structure, and fluorescence spectroscopy to monitor the tertiary and quaternary structural levels of complex biologics. Future efforts will also centre on the development and implementation of cutting-edge techniques for in-depth characterisation of native conformation on a local scale. This will further supplement existing capabilities by allowing site-specific and detailed conformational characterisation, that would be useful throughout all stages of protein drug development, from optimisation of target binding and receptor interaction(s) in research, to formulation, stability and comparability studies in process development, where information on changes in conformation could play an important role in the development and optimisation of complex biologics.

In order to demonstrate that methods are appropriate for use in drug development programmes, substantial time and resources are required. In the year ahead, our focus will be on method qualification and validation so that the assays currently being used are deemed compliant with international expectations, and most importantly, that the analytical data derived from these methods retain their full scientific value.

– Dr Stoyan Stoychev

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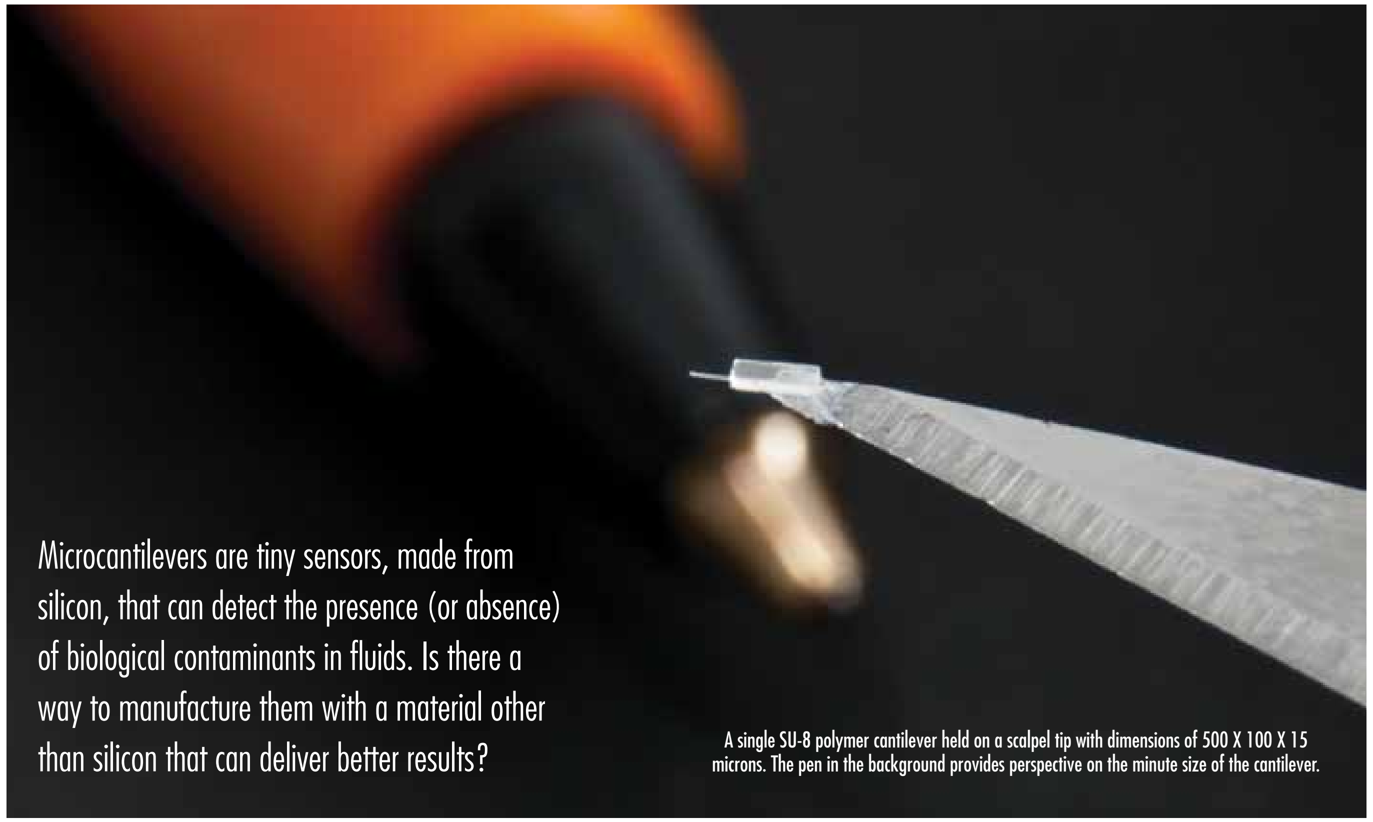
What are biologics?

A biologic is a prophylactic, an *in vivo* diagnostic or a therapeutic substance that:

- Is produced only by a living system, but is not simply a metabolite;
- Is stated to contain a single substance that has documented biological activity or activities;
- Has a relatively large molecular weight with a high structural complexity compared with biologically active substances that can be made by chemical synthesis; is inherently heterogeneous in the molecular species present, and has an impurity profile that depends critically upon the processes used to make and test each batch; and
- Has activity that is often very sensitive to physical conditions (i.e. temperature, shear forces, phase) and enzymatic action.

Microcantilevers: A future beyond silicon



Microcantilevers are tiny sensors, made from silicon, that can detect the presence (or absence) of biological contaminants in fluids. Is there a way to manufacture them with a material other than silicon that can deliver better results?

A single SU-8 polymer cantilever held on a scalpel tip with dimensions of 500 X 100 X 15 microns. The pen in the background provides perspective on the minute size of the cantilever.

TRADITIONALLY SILICON is used to manufacture microcantilevers because the micro-electronics manufacturing process suits microcantilever production so well; its properties are well known and a lot of infrastructure exists geared towards using silicon. However, when compared to polymer nanocomposites, silicon does not have a very wide range of stiffness and elasticity.

"How the microcantilever functions depends on the stiffness and elasticity of the material it is made from," explains Mark de Villiers, researcher with the CSIR's mechatronics and micro-manufacturing group. "They are used in sensing applications, such as detecting a specific contaminant in water or a virus in blood.

"For instance, if you were to design a microcantilever that has to detect *E.coli* bacteria, you would coat the surface of the device with *E.coli* antibodies. Should there be *E.coli* present in the sample, the device will be able to detect its presence once a bacterium adheres to the *E.coli* antibody on the surface of the cantilever," he says.

If not silicon...

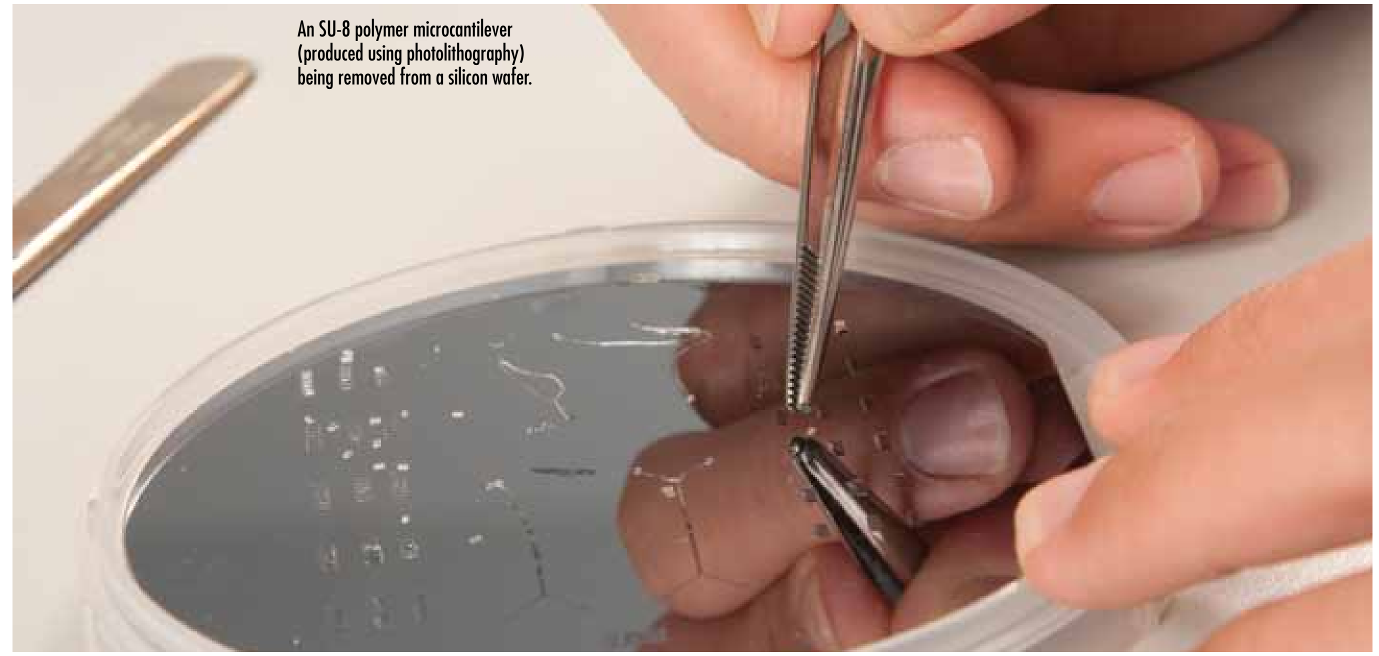
According to De Villiers, his research group chose polymer nanocomposites as a material to manufacture the micro-cantilevers, because nano-particles can be added in different concentrations to vary the elasticity and stiffness of the cantilever. This allows it to be tailored to better detect a certain analyte. For example, a heavier analyte may need a slightly stiffer composite than a lighter one. We also wanted a material that, for the same sample, would give a larger deflection than silicon."

Capturing the *E.coli* on the cantilever surface is only half of the microcantilever's work. The other half involves sensing.

Detection by deflection or resonance

De Villiers explains that there are two ways in which cantilevers can detect bacteria namely, deflection and resonant modes. Each mode has a number of methods that can be used to detect the presence of an analyte.

"In the deflection mode, when an analyte is present, the cantilever deflects (bends) due to surface stress changes or under the weight of the captured analyte. This can be sensed using different measures, one of which uses a laser beam that is reflected off the cantilever surface.



An SU-8 polymer microcantilever (produced using photolithography) being removed from a silicon wafer.

"In the resonant mode, when the cantilever captures a bacterium, the natural frequency of the cantilever changes due to the added weight. When excited by an external force the cantilever will resonate at its natural frequency. This frequency change is what is used to confirm the presence of the analyte.

"We are currently working on an optical sensing solution using a laser beam," he says.

Choosing a manufacturing process

There are also several options when it comes to the actual manufacturing process of the microcantilevers. One method that the team is exploring is micro-injection moulding, which involves injecting the polymer nanocomposite into a very small mould.

"Another method we are employing, typically used in the micro-electronics industry, is photolithography. Here a photosensitive polymer is exposed and developed into the shape of the cantilever. This is a method used to manufacture very precisely patterned devices such as microchips," says De Villiers.

A third method being investigated is micromachining, where one starts with a thin film made from the polymer nanocomposite material, and cuts the cantilevers out using a very narrow beam of ions.

"There are several other methods available, but we are experimenting only with these three," says De Villiers.

What the future holds

While the research team has already produced some micro-cantilevers, they hope to have a solid prototype ready by the end of this year. They plan to produce a hand-held or portable device that can easily detect a variety of contaminants in samples of fluid.

There are no local facilities readily available for producing these items commercially. A high-tech manufacturing plant would need to be set up or it would have to be outsourced to an international manufacturer. This too will depend on the manufacturing method chosen, as some methods are considerably more cost-effective than others. However, depending on the application, the market could potentially be substantial.

"If a hand-held sensor is available for rapid detection of, for instance, *E.coli* in drinking water, the market would be every local clinic or municipality and even more. Also, the impact would be huge – both in terms of the reduced cost of testing and the prevention of water-borne illnesses," concludes De Villiers.

The project is funded by the Technology Innovation Agency.

– Petro Lowies

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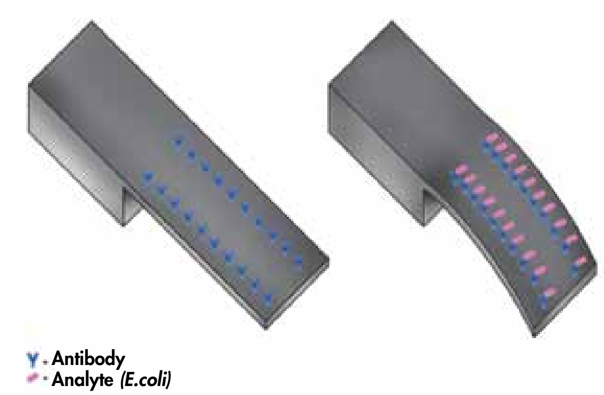
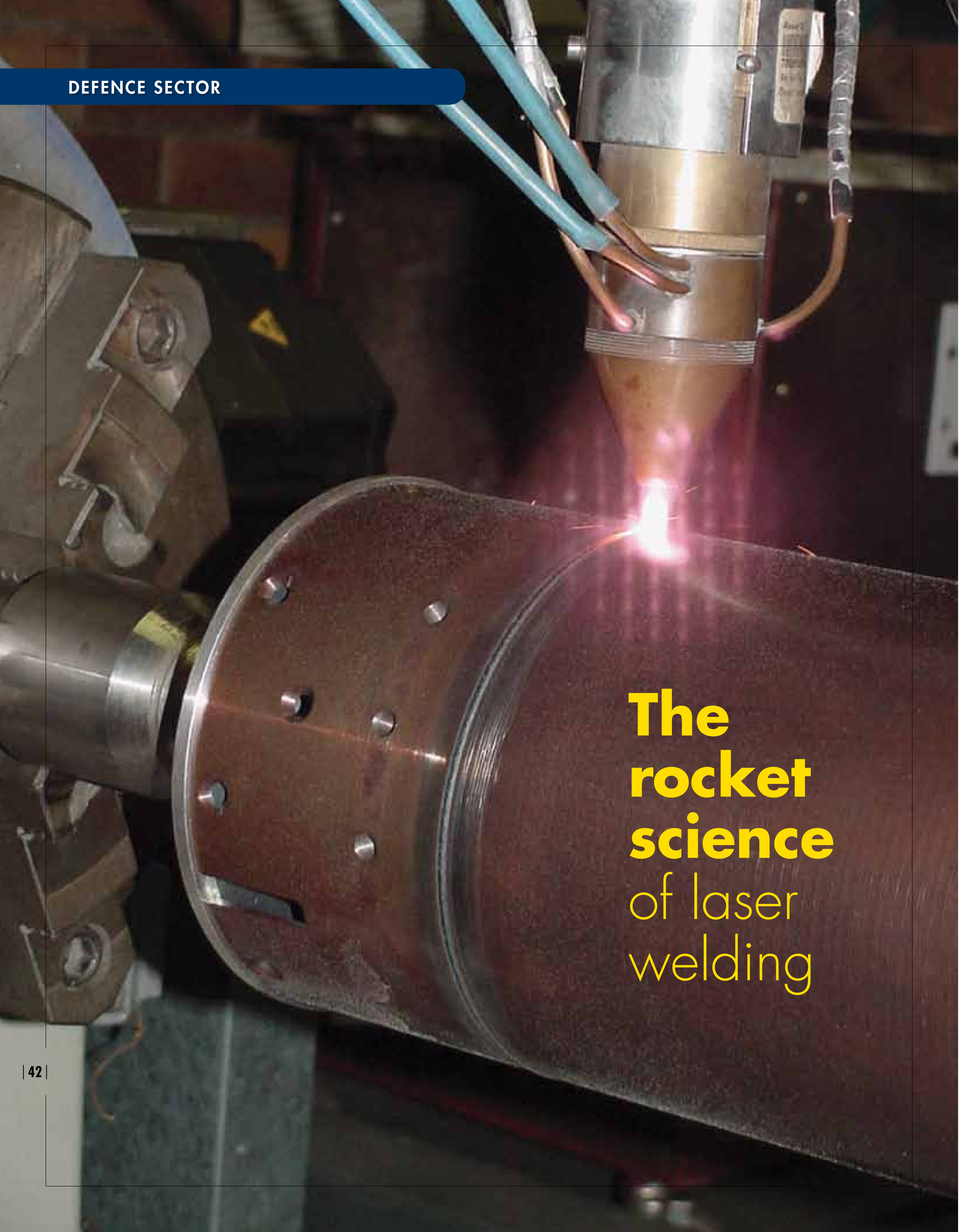
CSIR researcher Mark de Villiers, who works on the microcantilever project.



Left: Cantilever coated with antibodies
Right: Cantilever deflected due to presence of analyte bound to antibodies

A graphic representation of cantilevers that shows how the cantilever deflects once the analytes bind with the antibodies coated on its surface.



The rocket science of laser welding

Following the successful test-firing of the A-Darter fifth-generation short-range infrared homing air-to-air missile from the Gripen combat aircraft, the CSIR has been tasked with the production of a large batch of rocket motor casings by its industry partner, Rheinmetall Denel Munition. This production is specifically for the South African Air Force, that acquired a fleet of Gripen jets as part of its modernisation plan.

THE CSIR developed and implemented innovative and novel joining technology for the circumferential welding of thin-walled maraging steel on the A-Darter sections as well as the attachment of strake lugs to the walls of the tube.

The CSIR undertook the preproduction phase and according to project leader, Corney van Rooyen, everything went well. "This milestone demonstrates how we have evolved from an arc-welding process to the laser-based welding process," observes Van Rooyen. "Previously, Denel employed arc welding which presented challenges in terms of maintaining the very high quality-assurance requirements of this type of manufacturing.

"Our laser-based process," he explains, "is highly controllable, and therefore reproducible welds, with no weld defects, are readily obtained."

As a fully automated computer numeric control process, the laser-based welding is far less dependent on the operator. "Before this, the process relied heavily on skilled people to do the weld, but the process we came up with is essentially operator-independent."

"The biggest challenge on this project was the lug attachment to the casing," says Van Rooyen. "Not only is there a problem with accessibility, but with conventional arc-welding processes; it is always problematic to join components with very different thicknesses. The laser process, however, was able to overcome both these challenges.

"This is the beauty of laser processes compared to the conventional welding techniques," says Van Rooyen.

He says that without the laser, it would not have been possible to attach the lugs. "With Denel as our industry partner, we have assisted in producing a product that is truly world-class."

– Mzimasi Gcukumana

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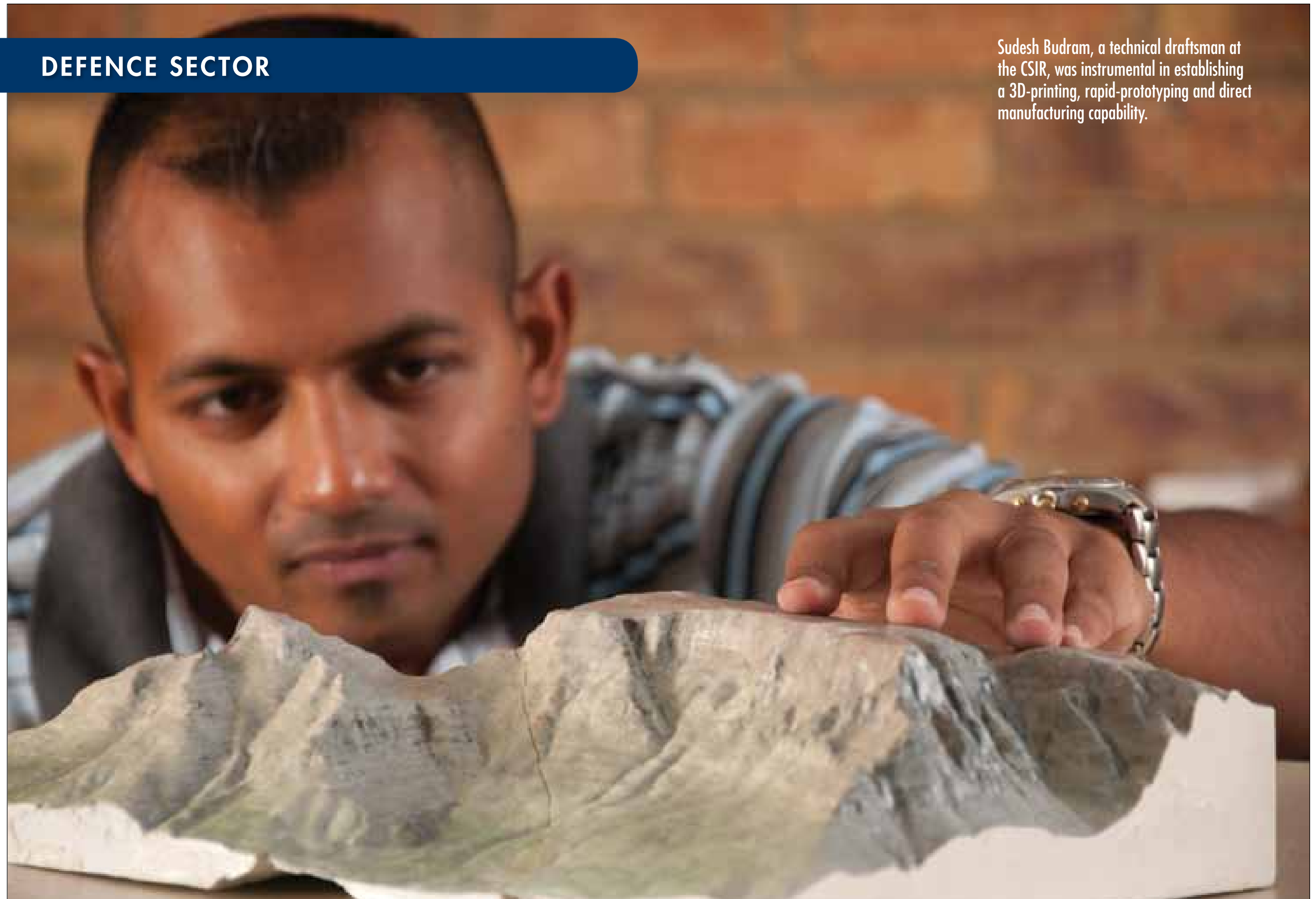
Laser welding of a rocket motor casing in progress.

about...

A rocket motor casing is typically a relatively thin metal that is lined with insulation to keep the propellant from burning through.



Sudesh Budram, a technical draftsman at the CSIR, was instrumental in establishing a 3D-printing, rapid-prototyping and direct manufacturing capability.

From drawing to tangible reality:
The artful science of direct manufacturing

CSIR clients can now benefit from a specialist capability that allows one to take a design, capture and simulate it digitally, and produce an actual, tangible object in hand. Previously known as rapid prototyping, direct manufacturing has changed the manner, and speed, by which a design can be turned into a physical prototype or model.

CHRIS SERFONTEIN heads the CSIR's technology for special operations group. His team focuses on technology solutions to address the unique requirements of the Special Operations cadres in the South African National Defence Force. In this field, rapidly created, custom and efficiently working solutions are critical. According to Serfontein, the challenge has always been the time and cost to produce the prototypes and products that can be provided to the client: "To date, manual and numerical-controlled manufacture has been the options available to us," he says. "Direct manufacturing technology is now considered mature and cost-effective enough to be procured as an extension to our capability."

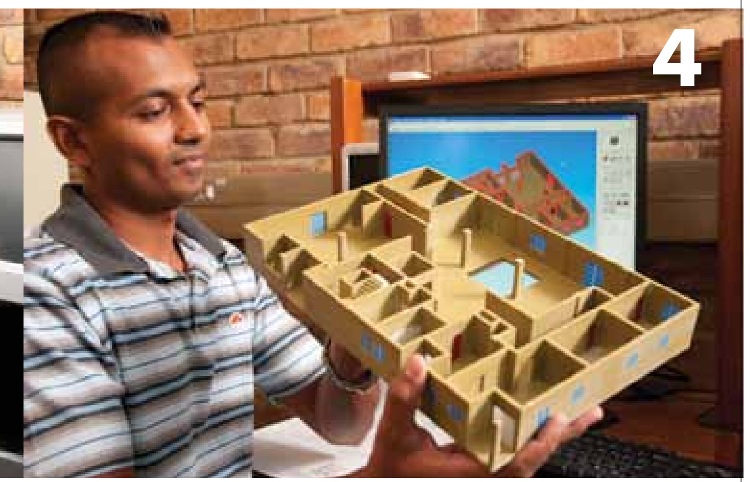
Direct manufacture comprises: The stereolithography apparatus (SLA) where a laser sets a layer of wax or photosensitive material in a bath; three-dimensional printing (3DP), which uses injection technology to create a thermo plastic structure; and selective laser sintering (SLS) that uses a laser to fuse powder (nylon, polycarbonate, polymer and metal).

None of these, however, can be used for colour terrain models. The CSIR therefore procured a 3D printer that uses colour ink jet technology. Serfontein says that the printer works like the normal printer that one would use to print a photograph, except that it does not print one layer per sheet of paper. "It prints layer upon layer, using a material that builds up on the previous layer of material," he says, adding, "Each layer is a 'picture' that slices through the object."

Data from 2D sketches are used as input to create a 3D model.

A model is built from a high-performance composite powder, after which post-processing commences.

Removal of powder allows for final preparation of the model.



The 3D model is inspected after the post-processing phase.

A frequent use of this printing capability is for the final production of 3D terrain products, based on the input data from CSIR geographical information systems experts, clearly showing all aspects of a terrain, as well as any specific information required by the client, in colour.

The input into the 3DP has to be created either in computer-aided design (CAD) software, or by using a 3D scanner to capture all dimensions of a particular object or shape.

"CAD has for many years been able to turn the designer's dream into a computer model. This has aided the design process significantly, but direct manufacture now gives the designer the ability to produce a complex model quickly and affordably," Serfontein says. This also enhances the advanced mechanical engineering capability, especially when complex mechanical engineering solutions are required. The technology thus has obvious benefits in terms of time-saving. It also reduces material waste associated with conventional forms of manufacture; lowers energy use; and allows for the design of unusual and more organic shapes and forms.

The designer can use direct manufacturing to produce the following: Scaled models of actual structures, terrains, areas, prototypes of parts, actual items (if a small volume is required and the material is acceptable); and as a high-production volume input to investment casting (for patterns), injection moulds (for hard tooling), sand moulds, and soft tooling (for cores).

Plans for the future are to expand collaboration in this field and make the expertise and facilities available more widely. Serfontein says that the CSIR is also working closely with Central University of Technology (CUT), Stellenbosch University and SoSolid in Cape Town to build a national rapid prototyping and direct manufacturing capability. "CUT has shown interest in collaborating with the CSIR in rapid manufacture research, and sharing knowledge and capability," he says, adding that CUT has an extensive capability of SLA, 3DP and SLS.

"We want to create a shared direct manufacture capability and service, including training with our national partners," Serfontein concludes.

The capability is not restricted to research and development efforts. It can be used by anyone who needs a design turned into an actual object as a prototype, scale model or test version. The team can, for example, create novel shapes for artistic use, ceramic design and models for architects or sculptors.

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CSIR experimentation in generating beams of exceptional brightness.

CSIR laser technology uptake to see a new range of lasers for international optics producer

The CSIR recently signed an agreement with one of the largest optics producers in the world, Carl Zeiss, to customise a CSIR-developed laser concept for a range of its lasers.

ACCORDING TO CSIR chief scientist and project leader, Prof Andrew Forbes, his team and engineers from the Pretoria-based company will attempt to incorporate the CSIR-designed and developed laser resonator concept into their system. "We hope to exceed the optical performance specifications without any fundamental changes to the system design," says Forbes. "It is worth noting that this work started in the laboratory as a project funded through the CSIR's parliamentary grant, resulted in published work in top journals and several awards for the students involved as well as invited lectures, and is now finding its way into industry."

Forbes adds: "It is always pleasing when an idea eventually makes it to a technology that is being taken up, especially by world-leading specialists." The technology makes it possible for almost any laser to operate in a 'high-brightness' mode, resulting in more efficient lasers used in, for example, long-range communication systems, and in the military for target designation.

The collaboration between the two organisations is funded by Carl Zeiss. The production plant for the lasers under development is located at Carl Zeiss' facilities at Centurion, South Africa.

"Such transfer of technology is necessary for South Africa to grow its knowledge-based economy," says Forbes.

The technology may also be used to make lasers smaller and less expensive, by exploiting the extra efficiency to make the support systems work a little less.

World's biggest optics maker fixes its sights on CSIR lasers

MANAGING DIRECTOR of Carl Zeiss Optronics South Africa, Kobus Viljoen, appreciates the relationship that his organisation enjoys with the CSIR. He says that this healthy relationship spans more than three decades and took on varying forms of technology collaboration over the years. This liaison has been further strengthened by the Department of Science and Technology's strategy on photonics, the Photonics Initiative of South Africa (PISA).

Viljoen's comments follow the signing of a one-year agreement between the two organisations. The agreement sees Carl Zeiss taking up a laser technology that was designed and developed by the CSIR mathematical optics group. Carl Zeiss will use the application in its range of optical products.

Carl Zeiss Optronics designs, develops and produces state-of-the-art optronic instruments for military and civilian applications. Under the new Carl Zeiss management, reveals Viljoen, the organisation is investing significantly in new technologies. "We invest 10% of our revenue back into research and development (R&D)," he notes.

He adds, "We've reached a stage where industry defines the technology that it wants. We will be using this technology in our next-generation products, such as laser rangefinders and laser designators – used in missile guidance. We have identified an application area where we needed technology and research, and the CSIR was able to provide that."

Laser partnership: From left, Dawie Mulder, project manager at Carl Zeiss, Dr Ndumiso Cingo, CSIR National Laser Centre manager, Kobus Viljoen, managing director of Carl Zeiss and Prof Andrew Forbes, CSIR chief scientist pictured after the signing of a year agreement at Carl Zeiss offices.

He says that this milestone is the tangible result of the PISA initiative.

Dawie Mulder, project manager at Carl Zeiss, adds that the objective is to develop lasers that can be used in military applications. "Our focus is very much on product development – sometimes at the expense of new technology development. Marrying the two is not an easy task," says Mulder, "but successfully doing so can really help separate your products from the rest."

Mulder elaborates, "The CSIR is the single best pool of knowledge in laser technology. It is a huge advantage for us to be able to improve our products' performance and efficiency based on the CSIR's R&D."

– Mzimasi Gcukumana

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A high-brightness laser explained

The concept

With lasers one generally has to choose between having lots of energy and having a 'nice' laser beam. A quality that incorporates both these parameters is the so-called 'brightness' of a laser: High brightness means good laser beam quality and high energy.

This is difficult to achieve because good beams tend to come at the expense of energy, while high-energy beams are highly distorted and difficult to use in practical applications. So is it possible to have the best of both worlds?

The research

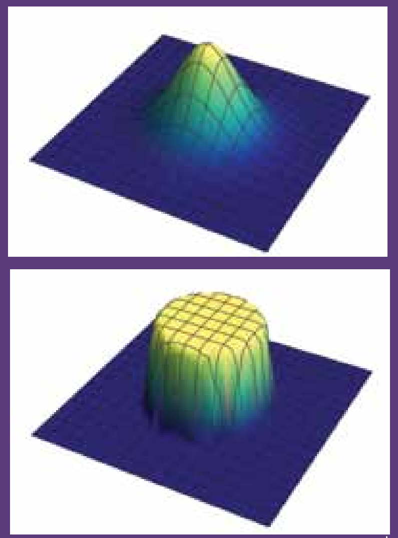
The CSIR has for several years invested in developing core expertise in shaping light with diffractive optical elements; optics that have feature sizes down to the micrometre scale, and sometimes to the nanometre scale.

The idea is that given a laser beam of a particular intensity profile (i.e. how the energy carried by the laser is distributed in space), it is possible to reshape the profile of this laser beam by redistributing the energy.

If this is done correctly, then in principle any laser beam shape can be achieved. The group worked on achieving this same result, but inside a laser, so that the diffractive optical elements are the mirrors of the laser.

The idea was that if the mirrors were correctly calculated and then fabricated, the laser itself would select the best beam for maximum brightness. The shape of the laser beam bouncing around inside the laser was chosen to extract as much energy as possible from the laser, but in a 'good' shape.

– Prof Andrew Forbes



A Gaussian beam (top) for good beam quality and a flat-top beam (bottom) for high energy. The CSIR produces a laser that combines both.

The CSIR's Francois Denner is the newly appointed coordinator of the Biocomposites Centre of Competence.

MASSIVE economic growth potential to be unlocked by the Biocomposites Centre of Competence

The potential size of a fully developed biocomposites industry in South Africa is estimated at R300 to R350 million per annum for rural fibre production, and R2 to R2.5 billion per annum for final (manufactured) products. A Biocomposites Centre of Competence was created with core funding by the Department of Science and Technology (DST), and co-investment from the CSIR, as a catalyst to unlock the potential of this industry.

A biocomposite is a material formed by a natural or renewable resource-based matrix (resin) and a reinforcement of natural fibres (usually derived from plants or cellulose).

Biocomposites are characterised by the fact that:

- The petrochemical resin is replaced by a vegetable or animal resin, and/or
- The reinforcement (e.g. fibreglass, carbon fibre or talc) is replaced by natural fibre (kenaf, sisal, hemp, flax, etc.).

science & technology
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REPUBLIC OF SOUTH AFRICA

ADVANCED BIOCOMPOSITES are materials developed through advanced manufacturing methods and are based on natural fibres such as kenaf, sisal, hemp, flax, bamboo, and others. Its development commonly involves resins and reinforcements that have been derived from a natural (growing) product as opposed to petrochemicals and man-made materials. It is therefore much more sustainable and environmentally friendly.

In South Africa, there are two key constraints to the wider commercial exploitation of advanced biocomposites. The first is the innovation chasm that exists between research and development (R&D) and the commercialisation phase of developed applications. The second is the lack of an industrial-scale demonstrator manufacturing facility to prototype, test and certify products and technologies.

It is all about growth

Garth Williams, director: advanced manufacturing technologies at DST, says that the biocomposites R&D-led Industrial Development Programme reflects the current strategic thinking of the department. "The notion of R&D-led industrial development sees technological innovation as a key enabler of socioeconomic development. This approach positions the DST in a central role in the country, with the department partnering with key stakeholders in government, industry and R&D organisations to bring about growth and employment through the development, demonstration, transfer and adoption of new technologies in the economy," says Williams.

The CSIR's Francois Denner is the newly appointed coordinator of the Biocomposites Centre of Competence. "My mandate is to build on the strong biocomposites competence base at the CSIR, and across the country. I am to establish a sustainable centre of competence in Port Elizabeth through the strengthening of current partnerships and the establishment of new ones. Ultimately the centre needs to facilitate the development of a viable biocomposites industry, which is currently fragmented and largely nascent," he observes.

What the centre will do

The Biocomposites Centre of Competence draws together the existing competences that lie with various institutions and industrial partners. These include, among others, industry (Sustainable Fibre Solutions, IDC, Sasol/ChemCity, Optimal Energy, Aerosud, Airbus, Experico, Acoustex, Perfect Places, etc); science councils (CSIR, Agricultural Research Council) and academia (such as the universities of Pretoria, the Witwatersrand, Cape Town, Johannesburg and the Free State; as well as Vaal, Central and Cape Peninsula universities of technology). The centre's node will be based at the CSIR.

The centre will focus on the development of an integrated biocomposites manufacturing industry by developing a set of product technologies across the biocomposites value chain for five targeted industries: Construction, packaging, automotive, aerospace and general moulded products.

Furthermore, the Biocomposites Centre of Competence has to increase the number of research and innovation specialists and practitioners orientated towards the needs of a biocomposites industry, and to increase mobility between science and industry sectors.

Products within three to four years

It is expected that the first products, aimed at the construction industry, will be commercialised within three to four years. There are currently several biocomposite products for this industry in the pipeline, varying from insulated roof sheets and tiles to power skirtings, and window and door assemblies.

Other markets where an international demand for biocomposite products exist include the packaging, aerospace and automotive industries. A number of new product technologies aimed at these high-value industries are currently in advanced stages of development.

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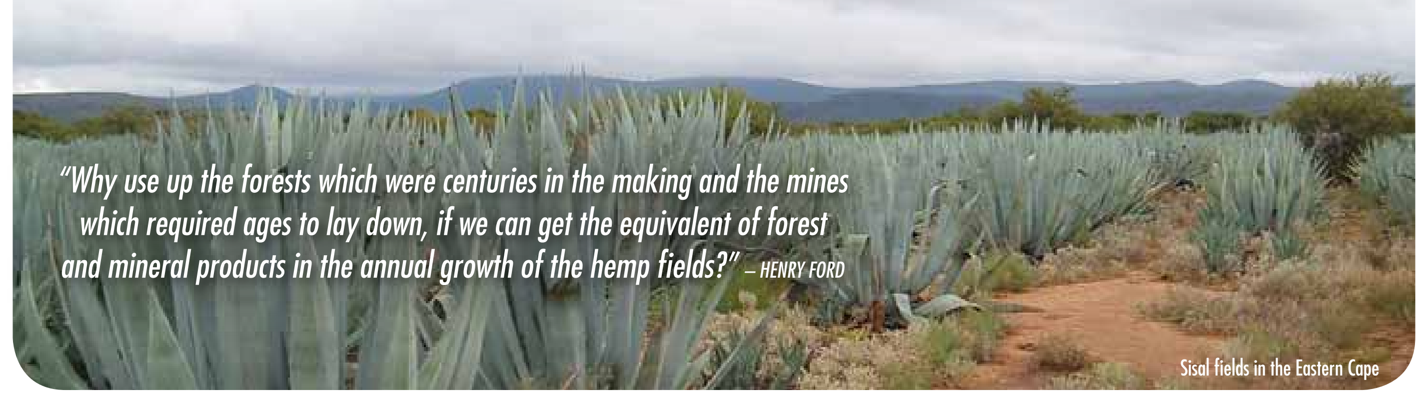
Did you know?

In 1941, the Ford Motor Company produced an automobile with a plastic body made from sisal, wheat, and primarily (70%) hemp. The plastic withstood blows 10 times as great as steel could without denting. Its weight was two-thirds that of a regular car. Its engine was designed to run with hemp-oil fuel.



"Why use up the forests which were centuries in the making and the mines which required ages to lay down, if we can get the equivalent of forest and mineral products in the annual growth of the hemp fields?" – HENRY FORD

Sisal fields in the Eastern Cape

Natural fibres such as flax (pictured here) are being used in biocomposites.

CSIR facilities geared to support the Biocomposites Centre of Competence

Over the past few years, the CSIR has made a significant investment into fibres and biocomposite research and infrastructure at its Port Elizabeth campus. The Department of Science and Technology (DST) has invested approximately R10.8 million in new equipment to complement this research. With the hub of the country's newly created Biocomposites Centre of Competence situated in Port Elizabeth, the CSIR is ideally positioned to provide optimum support.

THE MAJORITY OF RESEARCH done at the CSIR's facilities in Port Elizabeth focuses on nonwoven products and the more traditional fibre processing route. Fibre modification (where chemicals and techniques are applied to fibres to change their properties) also remains a strong focus, with continued support given to industry on fibres and textiles.

Research production area

This 4 300 m^2 facility includes extensive infrastructure for processing and analysing natural fibres and natural fibre-based composites along the whole value chain, from fibre extraction and processing, through intermediate products such as nonwovens, to final natural-fibre composite products and components. It is, essentially, a complete pilot production line.

According to principal researcher Dr Rajesh Anandjiwala, the CSIR's world-class nonwoven platform offers a unique, custom-made combination of several technologies for the production of a wide range of nonwoven fabrics and other related products.

"The processes involved in the pilot production line include fibre blending and opening; carding and cross lapping for web formation; needle-punching; hydro-entanglement; foam impregnation; hot air bonding; the curing and drying process; and hot calendaring and winding," he explains. "The pilot plant facility is also supplemented by a comprehensive range of testing instruments to characterise nonwoven materials for a variety of properties."

These instruments can test for air and water permeability; filtration efficiency, dynamic contact angle; surface tension; pore size and its distribution; water-vapour permeability; universal tensile testing with attachments for pull-out force and puncture resistance measurement; hydraulic transmissivity; as well as abrasion and peeling. In addition, digital image processing and microscopy analysis are also done.

Composites and biopolymers

"Composites are prepared using natural fibres such as flax, hemp, kenaf and agave; thermoplastic and thermoset resins; as well as biopolymers such as soy protein, polylactic acid and polyfurfuryl alcohol," Anandjiwala continues. "The mechanical, thermal, thermo-mechanical and fire-retardant properties of fibre-reinforced composites are optimised for application in the automotive and aerospace industries."

These two sectors are keen to increasingly use composites in the many parts needed in aircraft and cars, but materials used have to be strong as well as heat and fire resistant.

Developing new biopolymers and resins is an important activity in the development of biocomposites. For this, the CSIR's fully integrated composite processing facility includes a 2 700 kN compression moulding hydraulic press, vacuum-assisted resin transfer moulding, twin-screw extruder and an injection-moulding machine.

The composites laboratory houses state-of-the-art equipment for measuring the mechanical and thermal properties of composites. A weathering chamber was recently installed to study the influence of temperature, humidity and sunlight on composite materials, which are crucial for components that are used in outdoor environments.

Fire testing laboratory

Anandjiwala says that the facility also supports fire-retardancy testing. "The fire testing laboratory is being upgraded with the purchase of a rate-of-heat-release apparatus and a smoke density chamber."

Client and partnerships	Initiatives
Airbus	Interior panels for airplanes
Bombardier	Interior panels for train carriages
Volkswagen	Parcel tray
Experico	Packaging
Woolworths and suppliers	Characterisasion
De Gama, Frame, Brits Textiles	Natural fibre composites
University of Delaware	Biopolymers for housing
BIRN	International Biocomposites Network
IDC	Sisal fibre production
Sustainable Fibre Solutions	Kenaf processing
The House of Hemp and Hemporium	Establishment of hemp industry
Chemcity	Biocomposites for construction industry

Table: Examples of high-profile clients/partners and research initiatives

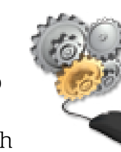
According to Anandjiwala, plans are afoot to seek approval for the fire testing laboratory from the Civil Aviation Authority. This will allow the CSIR to undertake fire testing according to Federal Aviation Administration standards. It will be the only facility of its kind on the African continent.

Not just research

Apart from research and development, this centre is also characterised by elements of industry seeking assistance with problem-solving, quality control, and guidance on maintaining ecological standards. In addition, the centre conducts hands-on training sessions for university students and the industry.

Anandjiwala concludes: "The CSIR's world-class researchers and well-equipped laboratories in Port Elizabeth have a valuable role to play in growing South Africa's natural fibre-reinforced composites industry, in close partnership with role players from academia, government and industry."

– Kelly-Anne Matthews



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DEVELOPING NATURAL FIBRE-BASED COMPOSITES FOR INDUSTRIAL APPLICATIONS

Current research programmes focus on the development of natural fibre composites for various industrial applications. An interesting product that has been developed is a natural fibre-reinforced sandwich panel for aircraft interiors. For the first time, natural fibre-based panels for aerospace applications have been developed using an environmentally benign flame-retardant treatment to comply with flame, smoke and toxicity (FST) requirements. The major advantages of these panels include being lightweight (leading to energy savings), environmentally friendly, fully degradable and sustainable. They are, therefore, truly 'green'. Other advantages include implementation of REACH (registration, evaluation, authorisation and restriction of chemicals) guidelines and alignment with the European Union's Clean Sky Initiative.

A natural fibre-reinforced composite is shown after fire testing.

Using locally available resources
to produce nanocomposites

Some materials have special properties when made in parts smaller than about 100 nm (nanometre). Nanoscience is the study and discovery of these new properties, and nanotechnology is their use in special products and applications. Prof Suprakas Sinha Ray, a world-renowned expert in nanocomposites, leads the Department of Science and Technology/CSIR National Centre for Nano-Structured Materials. The centre researches the production of nanocomposites and nanoparticles as well as their application.

SINHA RAY EXPLAINS, "Nanocomposites are considered an advanced material and their application presently lies mainly with the automotive and aerospace sectors." However, Dr Manfred Scriba, project leader of the industry-focused nanocomposites project, cautions, "Industry must seriously consider these materials for other applications in packaging, cosmetics and plastic products in general. In South Africa, polymer nanocomposites are not fully utilised and our industry runs the risk of falling behind."

Researchers at the National Centre for Nano-Structured Materials develop processes to produce nanoparticles and nanostructures with the intention of putting these into polymers (better known as plastics) to change their mechanical and thermal properties. Polymers can be made stronger, more stable at higher temperature or bio-degradable. The use of minerals with useful nanostructures, such as clays, is also being investigated.

Three examples of local clay (1,2,3) with modified clay (4), granulated polymers (5), and compounded pellets (6)

What are nanocomposites?

Polymers are carbon-based molecular chains. By themselves, they are quite soft. To improve strength, minerals and fibres can be added as filler. Once mixed, the polymer 'sticks' to the filler particles to gain composite strength.

In microcomposites, the interfacial surface area for this 'sticking' is relatively small. Thus, for a strong plastic, 20% or more of its weight must be filler. This has implications for cost, weight, and often the improvement in mechanical properties is not significant.

In nanocomposites the improvements are significant. The interfacial surface area between the polymer and the nanoparticles is much bigger. In nanoclays, for instance, due to similar sizes, a single polymer can find itself between two nanoparticles. This high-strengthening phenomenon is called intercalation and this nanoeffect is what makes it a true nanotechnology. Just 1% filler creates a plastic many times stronger than a microcomposite. It is also more flexible and can withstand higher temperatures.

Local clay makes a difference

Scriba's team of nanocomposite researchers has a singular task: To assess the suitability of local clays to be chemically modified and used as nanoparticles for nanocomposites.

He explains, "Southern Africa has an abundance of readily available, reasonably priced clay. We source clay from Mozambique, Namibia and, of course, South Africa."

Clay comes in a range of colours ranging from dirty white to fudge-brown, with the colour being an indication of purity; the colour indicates the presence of iron and other impurities. "The purer the clay, the more desirable it is for the production of polymer nanocomposites," says Scriba. While some deposits, such as the one found in Namibia, yield clays of high purity, the volume may be limited or more exploration is required.

One of the project members, Dr Jayita Bandyopadhyay, explains, "Clays are part of the Phyllosilicates family of minerals which were formed millions of years ago, often by the compaction and weathering of volcanic ash. The mineral consists of 1 nm thick silicate which is usually up to one micrometre wide, stuck together like a deck of playing cards." The trick for producing a proper nanocomposite is to develop chemical processes that modify the space between the layers so that they come apart and disperse evenly in the polymer during the nanocomposite formation.

While high-quality clays found in the US, Europe and Asia have been used extensively in nanocomposites, these are expensive to import, which limits their use. The CSIR project collects and evaluates the different clays found in southern Africa to investigate their chemical modification and suitability for nanocomposites. "As part of the project, we also decorate the clays with silver nanoparticles," says Dr Sreejarani Pillay, another project member. The well-known antimicrobial properties of silver together with the clay properties, make these nanocomposites highly sought after for inclusion in packaging material.

Researchers Dr Sreejarani Pillai, Boitumelo Motshabi, and Dr Jayita Bandyopadhyay in the nanocomposite lab

Once the modified nanoparticles have been evaluated (using instruments such as scanning and transmission electron microscopes, X-ray powder diffraction and thermogravimetric analysis), the final stage of the process commences.

Dr Joseph Hato, who is responsible for the compounding, explains that in order to produce the polymer nanocomposites, the modified clay and granulated polymers are fed into a compounder/extruder which melts and mixes the two materials. The final product is formed into pellets the size of grains of rice. These are, in turn, tested to assess the efficiency of the nanoparticles and nanostructures in the polymer. Desirable improvements might be a higher crystallisation temperature or better mechanical properties. Scriba confirms this, adding "Our innovation lies in the modification of the clays as well as understanding and optimising their incorporation in the polymer matrix."

The way forward

Beneficiation of South African minerals for use in advanced materials creates a strong value chain. Early indications are that nanocomposites produced with local clay show potential.

Scriba looks forward to working with industry to exploit the applications of nanocomposites, "We are keen to develop our technologies to meet the future demand of our partners in industry."

– Biffy van Rooyen

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Micromanufacturing:
The factories of the future

South Africa needs to invest in high-tech technologies to sustain economic growth in the medium to long term. Investing in micromanufacturing technologies might just be the perfect way to start.

SOUTH AFRICA'S manufacturing sector makes the second largest contribution to South Africa's Gross Domestic Product, contributing more than 50% of exports and employing about 1.7 million people.

Government knows that economic growth will not be sustainable on the back of raw material-driven exports only, and that it is imperative to continue developing a diversified, export-orientated manufacturing base. We are competing with Asia where low-cost manufacturing is the order of the day. This means that we need to move into higher value-added activities such as product research and development (R&D), design, high-end manufacturing, and product integration. Consequently, there has already been a marked increase in the introduction of high-end manufacturing and product tooling equipment in South Africa.

Importance of high-tech industries

In 2005, South Africa developed and implemented the Advanced Manufacturing Technology Strategy. This strategy highlighted the trend that distinguishes manufactured goods of different technology intensities. Research by Prof Sanjaya Lall of Oxford University showed that over the period 1985 to 1998, high-technology intensity industries in developing countries grew at over 20%, with electronic items dominating this category. Medium and low-technology intensity industries in these same countries grew by between 10% and 15%, while resource-based industries grew at just over 5%.

The trend in South Africa is no different. Clearly, high-technology manufacturing industries offer the greatest advantage for growth, which raises the question of what is required for South Africa to become competitive in these areas.

It is clear from the evidence, as well as other studies, that South Africa needs to invest in high-tech technologies to sustain economic growth in the medium to long term.

A very good example is South Korea, which decided in 1995 to focus on automotive and consumer electronics. Fifteen years later, we are all familiar with Samsung and LG Electronic products. One of the key technologies South Africa should focus on during the next 10 to 15 years is micro-manufacturing.

Micromanufacturing – the factories of the future?

Micromanufacturing is the fabrication of small integrated devices or systems that combine electrical and mechanical components. These components range in size from the sub-micrometre (or sub-micron) level to the millimetre level, and there can be any number, from a few to millions, in a particular system. Micromanufacturing extends the fabrication techniques developed for the integrated circuit industry, to add mechanical elements such as beams, gears, diaphragms, and springs to devices.

Micromanufacturing technologies will have a profound impact on future technology developments in practically all sectors of industrial activity, from consumer products to more complex and new applications. It makes use of a broad variety of materials, components and basic technologies and provides functionality and intelligence to highly miniaturised systems, which can perform unprecedented tasks, or add new capabilities and performances to traditional equipment, machines and materials.

These technologies have further been labelled as a disruptive technology that will have a profound impact in the societal and social economic arena, providing affordable solutions to the developing world, in terms of health care and point-of-service delivery. It further has real economic value due to its cross-cutting nature and could be applied in any industry or application.

Examples of micro-manufacturing products include inkjet printer cartridges, accelerometers, miniature robots, micro-engines, locks, inertial sensors, microtransmissions, micro-mirrors, micro-actuators, optical scanners, fluid pumps, transducers, and chemical pressure and flow sensors.

New applications are emerging as the existing technology is applied to the miniaturisation and integration of conventional devices. These systems can sense, control and activate mechanical processes on the micro scale, and function individually or in arrays to generate effects on the macro scale. Micromanufacturing technology allows one to develop and manufacture a great range of devices, which individually performs simple tasks, but in combination can accomplish complicated functions.

It is critical for South Africa to think about the future of manufacturing and start to invest today in R&D to secure a competitive advantage in 20 years' time. Realising this, the CSIR has started to invest in micromanufacturing research (since 2008), as well as establishing the first micromanufacturing research group in South Africa with very strong international ties. The CSIR would like to collaborate with other research groups and organisations in South Africa, as well as industry players interested in the development of micro-manufacturing products.

– Riaan Coetzee

Micromanufacturing technologies will have a profound impact on future technology developments in practically all sectors of industrial activity, from consumer products to more complex and new applications.

It has also been labelled a disruptive technology that will have a profound impact in the societal and social economic arena, providing affordable solutions to the developing world, in terms of health care and point-of-service delivery.

The CSIR's Jerry Chen undertaking wafer preparation using the soft lithography process.

Researchers in the micro-manufacturing laboratory

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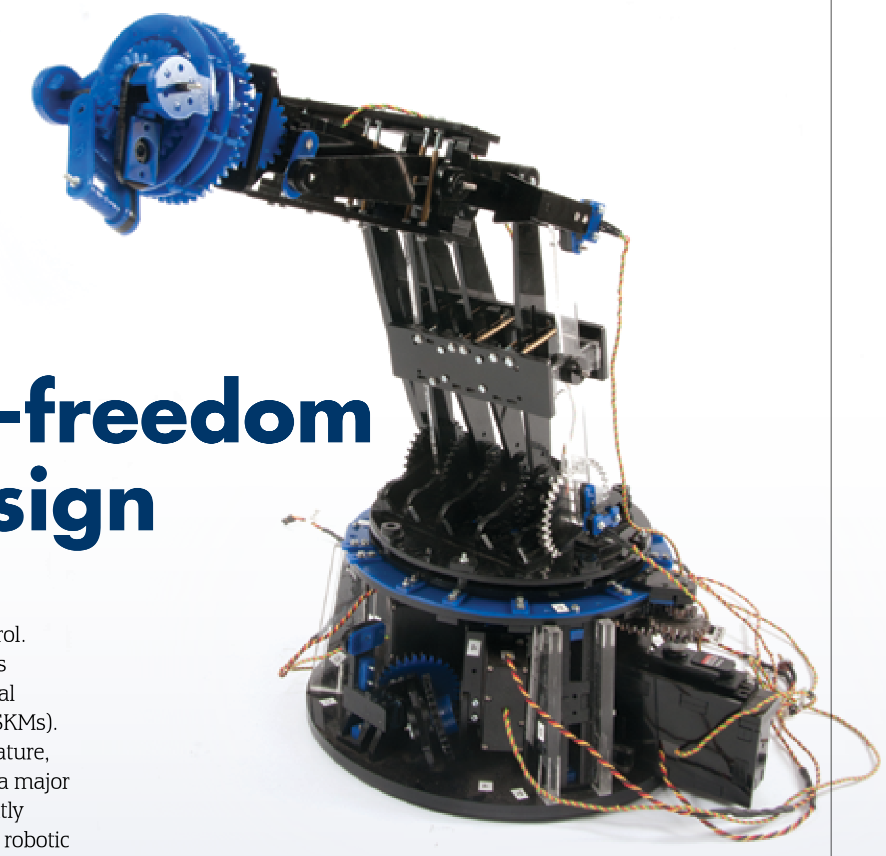
Ahmed Shaik with a scaled model of one design concept, which has all motors at a fixed location.



A novel, six-degree-of-freedom robot arm design

The CSIR is combining two methods of robot design to offer a solution that could substantially reduce robots' power consumption, while they perform the same tasks.

THE TROUBLE WITH COMMON robotic arms is that their design fixes large motors and gear boxes to their movable axes. This makes the arms heavy, and the heavier the object, the more energy is required to move it. Engineers at the CSIR are hard at work solving this problem by using a hybrid robot design that they say could be more energy efficient, resulting in cost savings over the lifespan of the robot.

Robotic arm architecture

Robotic arms can be programmed to accomplish a wide variety of tasks within their workspace. Some of the uses of robotic arms include component assembly; welding; cutting and spray painting.

A central design feature in commonly used robotic arms is that their motors and gearboxes are located at, or close to, the specific joint they control. Robots designed in this manner are called Serial Kinematic Machines (SKMs). Though simple and mature, serial architecture has a major drawback. It significantly increases the inertia in robotic arms. Increased inertia also affects accuracy by contributing to dynamic vibration problems.

To solve the problem common to SKMs, parallel architecture was developed. In most Parallel Kinematic Machines (PKMs), all the motors and gear boxes have a fixed arrangement and position in space. A number of arms and links are coupled in parallel from the motors and gear boxes to the grasping mechanism or tool at the end, forming closed kinematic chains. As such, the motors and gearboxes remain stationary relative to the movement of the robotic arm. However, parallel architectures are not without problems, the most significant being the sizeable machine footprint in comparison to the useable workspace.

The best of both worlds

The solution lies in using a hybrid design to combine the strengths of both architectures, says Ahmed Shaik, an engineer at the CSIR's mechatronics and micromanufacturing group.

A hybrid design allows for an optimised workspace-to-footprint-ratio equivalent to that of a serial robot. It also has a machine-moving-mass and agility closer to that of a parallel robot.

"The design that we are working on is unique, consisting of patented mechanisms that enable a full range of six degrees of freedom. The design centres on the concept of fixing the heavy-duty motors in one location and transferring actuation to a specific axis located elsewhere via a unique concentric gearing mechanism and other sets of gears and light-weight connected linkages," explains Shaik.

"Actuation transfer from the base-gearing system can be realised either with rigid links, toothed belts or chains. It would have to transfer torque along multiple configurations of the robot arms' main proximal and distal links to the respective wrist mechanism as efficiently as possible," he adds.

An energy saver for industry

Shaik states that their Hybrid Kinematics Machine (HKM) design could have a significant impact on power consumption in industry, "This particular design reduces the total moving mass of the robotic arm."

"If this HKM were to replace the popular SKM, having the same lifespan and performing the same tasks, it should be more energy efficient and result in substantial cost saving for industry over the long term," he adds.

– Bandile Sikwane

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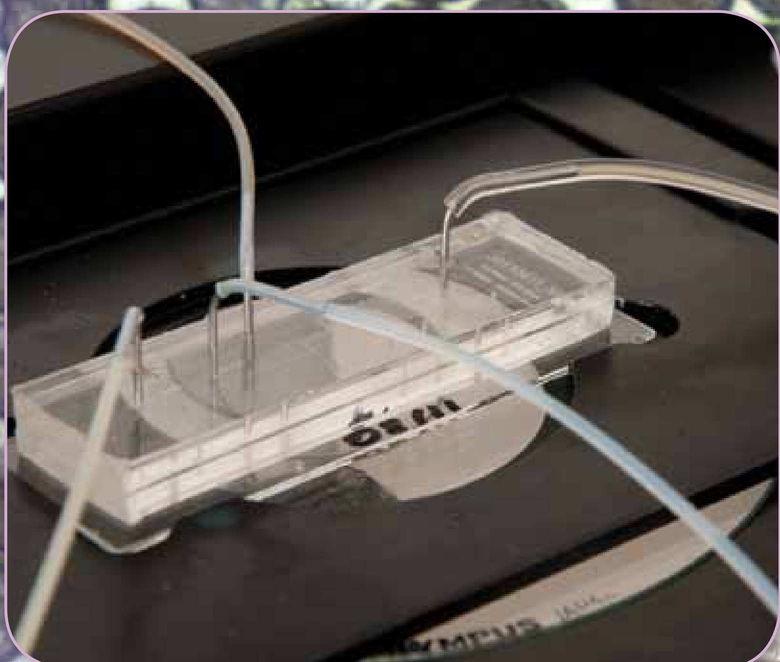
Self-immobilised enzymes manufactured through droplet microfuidics.



The microfluidic device used to manufacture the particles.

Microfluidics researcher Mesuli Mbanjwa separates manufactured microparticles from oil using a centrifuge.

Particle manufacture for industrial applications – **better control through microfluidics**

One of the newest research outflows of the miniaturisation revolution is the use of controllably produced microdroplets. When this technology is perfected, it will represent a technological leap in the quest for biological and chemical applications.

"**MICROFLUIDIC MICRODROPLETS** are manufactured such that they are controlled in both their physical size and structure," explains Kevin Land, principal technologist and project leader for microfluidics at the CSIR. "They are produced by means of microfluidics which, in simple terms, describes the study and development of systems that manipulate, process and control small volumes of fluids."

Simplified further, a microfluidic device has a minute channel through which two immiscible fluids are squeezed. One of the fluids then breaks up, through a process called flow focusing, into tiny (nanolitre or picolitre volumes) droplets.

But why are scientists interested in making these droplets? Basically, each of the droplets has the potential to be a micro-reactor – the central concept is to carry out entire experiments in small droplets, allowing for isolation of the reactions – making the experiment controllable to a degree not previously achievable.

Droplets-on-demand

The droplet microfluidics can also be used to create monodisperse particles (particles of similar size) and gels, which are beneficial for many health-related diagnostic, drug encapsulation and industrial production applications. One specific application is self-immobilised enzymes (used as biocatalysts that can modify or speed up chemical and biological reactions).

Says Land: "Free enzymes, used as biocatalysts, are very difficult to recover and re-use. Self-immobilised enzymes, however, can be used and then recovered. This makes them more cost-effective and environmentally friendly."

Land's team of researchers has been focusing on microfluidics for the past two years. These self-immobilised enzymes are one of the projects that flowed from their work on producing droplets that can be controlled. The work seeks to improve the method of making the self-immobilised enzymes by using droplet microfluidics. "One advantage of using microfluidics to produce these controlled droplets is that it allows for the precise introduction and mixing of reagents. This means the reaction times are faster and the droplets that will become particles can be manufactured much more controllably than with conventional batch systems," he says.

A platform to support particle manufacturing

"We now have an easy-to-use and reliable system and solid droplet platform that can be used to tailor an application according to the needs of any industrial partner," states Land. "These include the right people as well as facilities such as laboratories for experimental and characterisation needs and a clean room. I believe that we are the only facility in the country that uses this method to produce controlled droplets or particles. The fact that it is adaptable to any application also makes it an attractive option to consider."

He concludes: "I echo the sentiments of Heubner et al, who came to the following conclusion in a 2008 article: The ability to reproducibly generate, process and analyse isolated droplets of varying composition and at high frequencies defines a colossal leap in technology for large-scale biological experimentation. Even though such droplet technologies are in their early years, the power is convincing."

– Petro Lowies

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Future challenges see industry finding its way to **high performance computing**

South Africa's Centre for High Performance Computing (CHPC) now has over 500 users from across the science and engineering domains. Traditional users of the centre have been higher education institutions and research councils. However, ever-mounting pressures on industry to grow their business and to become more competitive, have led a number of companies to the CHPC.

THE CSIR'S strategy for the advanced manufacturing industry seeks to achieve significant impact through the development and transfer of manufacturing technologies that improve the competitiveness of existing South African industry while also creating new manufacturing opportunities. CHPC industry partners such as Sasol, Hatch and others are using the facility to conduct computationally intensive research that seeks to advance their products and increase their competitive edge. They have access to the facilities without long-term commitment, which translates to cost-effective access.

Some of the functionality and services that South African industry has access to, include:

- Cluster usage resources
- Training on cluster platforms and related services
- Storage resources
- Backup and archiving solutions
- Technical support and services.

There are three ways in which industry can access CHPC facilities. The first is through Computer Processing Unit (CPU) rental on a cost-recovery basis. This option is specifically designed for industry with established research and development (R&D) functions. The second option is for industry without an R&D function, where the CHPC can provide consultancy on simulation and expertise. The third option is a combination of CPU rental and consultancy.

To improve service to industry, the CHPC 2011 national meeting established an Industrial Advisory Council. The council, made up of CHPC users from industry, meets twice annually and is a platform for South African companies to provide advice on CHPC policy, strategy and implementation as these pertains to industry. It is a forum to identify and discuss competitive issues around HPC adoption, use, and more generally industrial computing for design, manufacturing, and services that are important to the South African economy.

"The nature of the research objectives of CHPC's newer users from industry falls into the priority themes identified by the CSIR in its strategies for advanced manufacturing, for example advanced production and processes, knowledge-intensive manufacturing and smart products and systems. This makes the CHPC a partner for development that is geared towards developing strategic partnerships with key industry role-players who are eager to explore and adopt new technologies," says Dr Happy Sithole, CHPC director.

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Dr Happy Sithole, CHPC director, left, and Giullio Capuzzimati, Industrial Minerals Director, Hatch, signing the service level agreement between the CHPC and Hatch. Hatch is an international company with services in mining, energy, infrastructure and technologies.

The CSIR's Denan Kuni, Kobus Roux and Kagiso Mnisi of the MNCC Office.

CSIR hosts the Multinational Companies Cooperation office

Harnessing the power of private-public ICT partnerships

The CSIR has been appointed by the Department of Science and Technology (DST) to host the Multinational Companies Cooperation (MNCC) office. Its primary role is to assist the DST in structuring, guiding and monitoring engagements with multinationals in the information and communications technology (ICT) sector.

WITHIN THE CONTEXT of the National Research and Development Strategy (NRDS), the DST leads the development and implementation of the national ICT research, development and innovation (RDI) strategy. Its goal is to create an enabling environment in South Africa for ICT RDI to flourish to the benefit of different sectors, and ultimately to help the growth of the South African economy.

The CSIR's MNCC office provides the vehicle for collaboration with relevant stakeholders and assists in the formulation and management of joint initiatives. Overall, it forms part of a new drive by the DST to partner with the private sector in furthering South Africa's ICT RDI objectives, which support priorities such as enterprise development and advanced manufacturing.

This new drive is informed by the DST's ICT Implementation Roadmap. The activities in the ICT RDI programme will be based on six thematic clusters namely, broadband infrastructure and services, ICT for development, sustainability and environment, industry applications (including advanced manufacturing), grand science, and the service economy.

Operating within a framework

In 2011, the ICT RDI roadmap confirmed the importance of effective collaborative partnerships between science councils, higher education institutions, government and the private sector, in enabling ICT and the knowledge economy.

The DST's MNCC framework provides a structured, streamlined and effective process for fostering partnerships with multinational ICT companies. The CSIR's Kobus Roux who heads the MNCC office, explains, "At the CSIR Meraka Institute, we have the technological and scientific know-how and the interest to assist in realising benefits for all partners through the MNCC's activities. The framework is a platform for the development of mutually beneficial programmes and projects for both the DST and government on one hand, and the concerned MNC on the other hand. By solidifying and implementing DST partnerships with MNCs, we envisage important outcomes such as human capital development, and development of new local intellectual property (IP)."

The partnership with SAP Research Internet Application and Services Africa, has been productive in terms of postgraduate students: Over the past five years the collaboration has seen the enrolment of 16 undergraduate interns and postgraduate students, notably 14 Master's and 17 PhDs. Seven degrees have been completed. These includes six Master's and one PhD. The work has also resulted in the development of a new South African mobile technology that will be exploited globally.

The partnership with Microsoft hosted the national finals of the Imagine Cup, a competition to encourage young talent to develop ICT solutions for relevant local challenges, in domains as diverse as manufacturing and health. The Centre for High Performance Computing and climate scientists at the CSIR are collaborating with Microsoft's Cambridge facilities on climate change modelling. The CSIR Meraka Institute is also developing, with Microsoft, new models for the use of ICTs in small and rural enterprise development.

Through the collaboration with Nokia, mobile learning for maths and the Open Innovation Africa Summit (OIAS) have been implemented; the collaboration is also aiming to bring a number of programmes to South Africa, including the Universal Access to Mobile Technologies and Services Programme, and the Research Ambassadors Programme. In another related activity, Laurens Cloete, Executive Director: CSIR Meraka Institute, joined a group of invited South African participants at a roundtable in February 2012 with Nokia CEO, Stephen Elop, held at Vodaworld in Midrand. The discussion topic was the South African mobile applications and services ecosystem.

Over the course of 2012, the DST and the CSIR plan to partner with other ICT MNCs such as IBM, Cisco and others, as well as establishing and growing a local industry partnerships framework aimed at strengthening the NRDS and the ICT RDI objectives.

"The MNCC is poised to fulfil its mandate as an implementation agency for the DST and stands ready to support industry through private-public ICT partnerships," concludes Roux.

– Biffy van Rooyen

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A risk and control framework
for cloud computing and virtualisation

The evolution of manufacturing has given rise to computer-aided manufacturing, reconfigurable manufacturing systems and technology-intensive manufacturing. This in turn requires that new options for computing capability are investigated.

ORGANISATIONS HAVE TO ADAPT quickly to changes to retain a competitive advantage and meet targets. Reduced costs, scalability, flexibility, capacity utilisation, higher efficiencies, and mobility can be achieved through technologies such as cloud computing and virtualisation.

To assist organisations with compliance and governance relating to these technologies, the CSIR's Enterprise Knowledge Engineering and Management group has developed a risk and control framework for cloud computing and virtualisation, named the Cloud-V Framework.

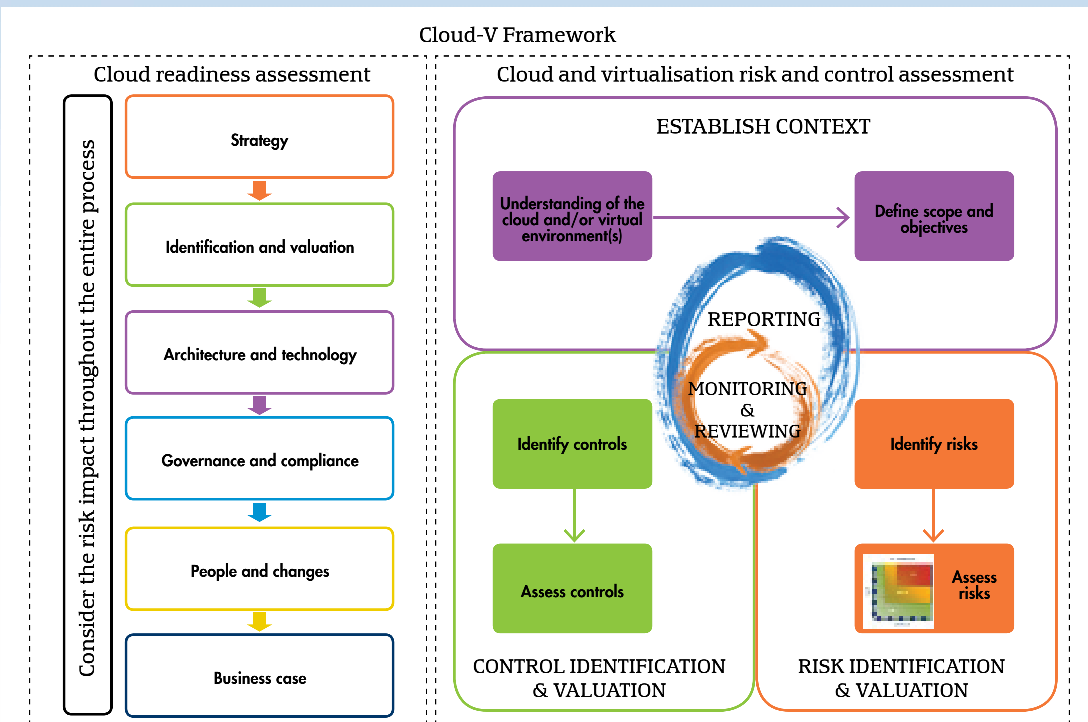
Cloud-V Framework

Cloud computing and virtualisation have gained clear acceptance in the information technology (IT) industry, with strong indications of a significant future. Yet threats from centralised and shared resources now exceed the adoption of these technologies. Why is this so?

The reality is that although virtualisation allows users to access power beyond their own physical IT environment; this is associated with many risks. Within the cloud environment, data are no longer under the control of management, and uncontrolled or unforeseen risks and threats can lead to a company's information being compromised.

The Cloud-V Framework provides a governance structure and guidelines for the identification and assessment of cloud computing and virtualisation risks, and controls to mitigate the identified risks. It was developed by Mariana Carroll, a CSIR PhD student. Professors Paula Kotzé and Alta van der Merwe are Carroll's PhD supervisors.

The Cloud-V Framework provides guidance to determine an organisation's readiness for the deployment of assets into the cloud. It also offers a detailed set of methods to guide the understanding and identification of risks and controls to maximise the value of cloud computing and virtualisation. Guidelines to assist in protecting and safeguarding applications and data, and meeting regulatory requirements pertaining to the cloud and virtual environments, are included.



The risk and control framework aims to serve a diverse audience based on their distinct needs, including business leaders, management, and information systems professionals; those charged with IT governance and providing cloud computing and virtualisation services; and IT assurance and compliance auditors or consultants.

– Mariana Carroll, Prof Paula Kotzé and Prof Alta van der Merwe

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The Cloud-V Framework was recently used in an assessment of access and authentication to a large enterprise resource planning application running in a private/community cloud at a prominent international beverage company where the cloud and virtualised environment is provided by a major IT company.

Feedback from the Line of Business manager included: "The cloud assessment is a must-have for any organisation considering a cloud-based solution of any kind. The value derived from the assessment gives clear guidance around the potential pitfalls and has broadened our thinking around cloud. My hope is that this assessment becomes an industry standard for all organisations to measure their cloud readiness against."


Prof Paula Kotzé (back) and Mariana Carroll

What is cloud computing?

Cloud computing is the delivery of computing as a service rather than a product. Shared resources, software and information are provided to computers and other devices with access via a web browser or a desktop or mobile application, as a metered service over a network (typically the Internet). Cloud users do not need to know the location and other details of the computing infrastructure.

Cloud computing is a model for enabling convenient, on-demand network access to a shared pool of configurable computer resources that can be rapidly provisioned and released with minimal management effort or service provider interaction.

The market for cloud technology and integrated services is currently transforming from the hype cycle to testing, piloting, and implementation by larger enterprises. Given the potential for significant cost savings, smaller and medium-sized organisations are also becoming early adopters of this technology.

CSIR experts in laser sources Kwanele Nyangaza, left, and Gary King assembling a state-of-the-art solid-state laser.

Advanced photonics manufacturing facility to ensure new laser-based products

The CSIR is set to establish an advanced photonics manufacturing facility to bridge the gap between laboratory demonstrators and commercial products. This will allow the transfer of laser technology in the form of advanced photonics products to the South African and international industries, says Dr Daniel Esser, project manager and laser sources research group leader.

THE CSIR IS KEEN to collaborate with existing and new industrial partners to develop niche products that could provide South African industry with a competitive advantage.

"One of the cornerstones of the strategy is to build and support programmes that will stimulate growth in this important technology sector," explains Hardus Greyling of the CSIR. "The establishment of such a facility will therefore directly support the photonics strategy by creating an environment where technological innovation can be transferred in a structured way to industrial partners."

Esser adds: "This will be a well-equipped facility, with the mindset of advanced product development, in contrast to a research lab."

He says that the goal of the facility supports the CSIR's strategy around advanced manufacturing and smart product development.

The CSIR is known for demonstrating state-of-the-art laser technologies. "Our focus now is to develop these lasers to a state which can be adopted by industry," says Esser. "Researchers in this area have already identified niche application areas made possible through the unique properties and wavelengths of our laser technology.

"The unique proposition resulting from our technology is rugged mounting techniques, thermal management, and in-depth knowledge of solid-state laser systems," he says. "This is what has put our laser technology demonstrators at the leading-edge of innovation."

The CSIR holds more than five world records relating to groundbreaking discoveries in laser sources, made in recent years. "These lasers can be used for a number of tasks, including medical applications, due to their unique wavelength," explains Esser. These world records were recognised by the international community in the form of published papers and international invited talks.

"More importantly however, we have produced technology demonstrators for each of the new concepts which have been acknowledged by local stakeholders," says Esser. "The next step is to take these technology demonstrators to advanced products. To do this, we need to put in place an advanced photonics manufacturing facility."

– Mzimasi Gcukumana

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Water tank leaks at Koeberg Power Station sealed with new laser process

Following the successful demonstration of a world-first laser-cladding process two years ago, the CSIR and Eskom welding engineers recently tested this technology during a scheduled maintenance operation at Koeberg Power Station, Cape Town.

THE PROVISIONALLY PATENTED laser beam-welding and leak-sealing technology was developed for Eskom in collaboration with Eskom welding engineers. The technology provides significant support in the maintenance of South Africa's power stations, particularly in sealing and repairing leaking water vessels without having to drain them before conducting the repair work.

During 2011, CSIR laser engineers Herman Rossouw and Corney van Rooyen as well as Eskom welding engineer Philip Doubell repaired a unit water storage tank in a drained condition during a scheduled maintenance outage. This feat was eclipsed in February 2012 when the same team sealed cracks on another tank – fully charged with water, and the unit on full generating mode. "The idea was to perform the work without impacting on Koeberg's power generation capacity," says the CSIR's Herman Burger.

According to Eskom's engineering programmes manager, Anton Kotze, the maintenance work was successfully completed by the CSIR in collaboration with Eskom's research, technology and development team with the required leak sealing and overlays being applied in eight areas on the refuelling water storage tank.

"This is probably the first time that laser-based refurbishment technology was used for leak sealing in the nuclear power industry," says Burger.

"We would like to express our appreciation for the efforts made by CSIR engineers – Herman Rossouw and Corney van Rooyen – and their work ethic, professionalism and positive attitude," says Kotze.

Previously, the 18 m high stainless steel tank with its 15 m diameter was refurbished using arc-welding processes. "These caused undesirable effects such as thermal distortion. The very low heat input associated with the CSIR's laser process eliminates these problems and in addition enables Eskom to use local suppliers to conduct refurbishment activities of this nature," explains Burger.

He says that the success of the refurbishment work – during a scheduled maintenance downtime – is a telling example of the strategic importance of laser technology for industry. "In an environment with stringent requirements on quality and turnaround time, we successfully performed work that has not been done in South Africa before," notes Burger.

Eskom's nuclear spokesperson, Tony Stott, commented on the excellent, safe and innovative approach used in conducting this refurbishment work. "The success of the project is attributed to the continued dedication of the CSIR and the sound partnership with Eskom," states Stott.

– Mzimasi Gcukumana

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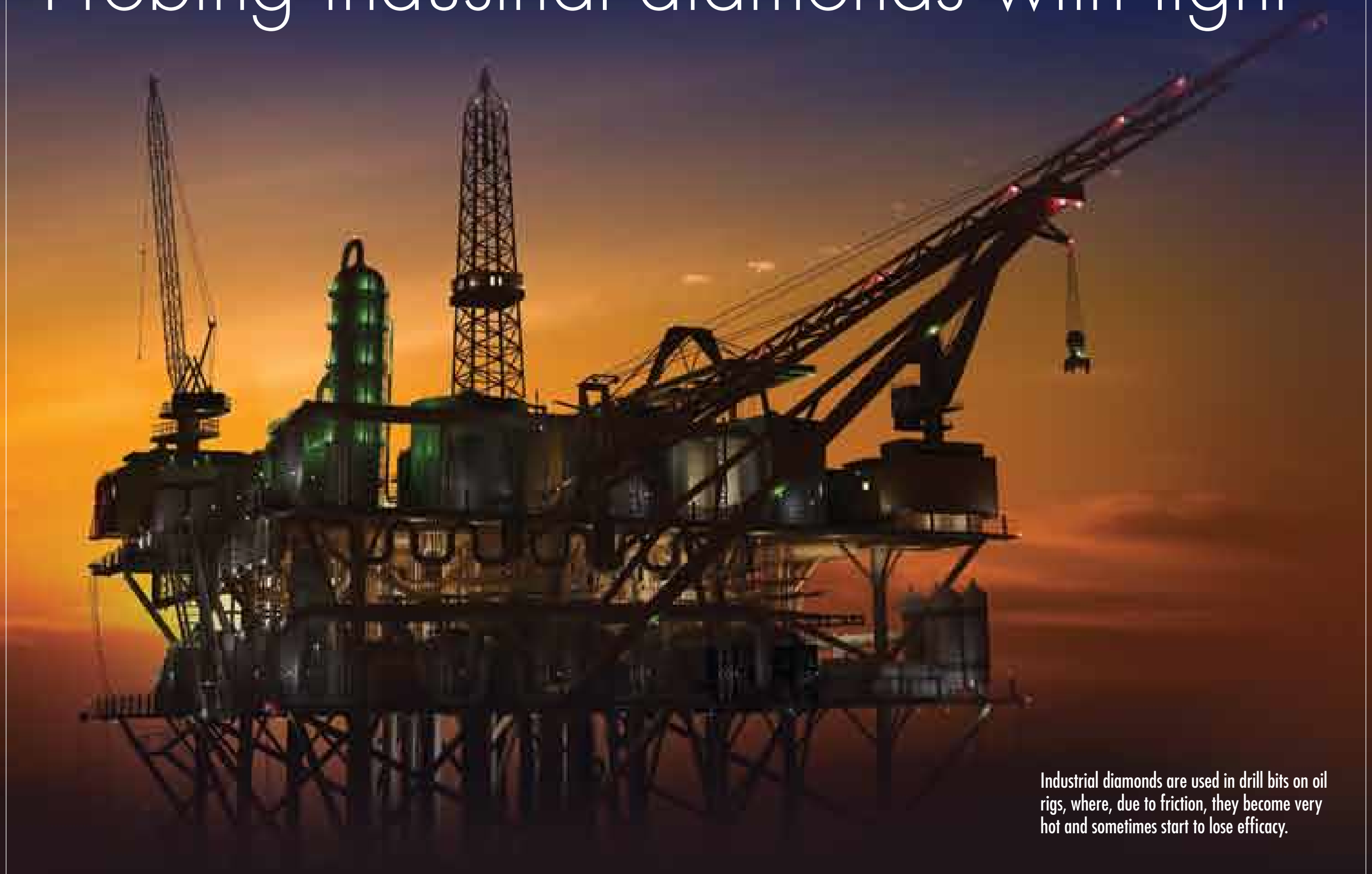
The water storage tank at Koeberg that has been repaired with a new laser process, while in use.

The process as seen up close.

Probing industrial diamonds with light



Industrial diamonds are used in drill bits on oil rigs, where, due to friction, they become very hot and sometimes start to lose efficacy.

The CSIR has developed an in-house technique for the heating, and subsequent temperature measurement of industrial diamonds. This technique, which is non-invasive and uses only light for both the heating and measurement, is now used in collaboration with our industrial partner to improve the efficacy of their diamond drilling tools.

Back to basics

Around 100 years ago, physicists discovered the nature of blackbodies: Objects that exhibit the particular trait that the colour of the light they emit is dependent only on the temperature of the body, and not on its shape or size. In fact, the hotter the object, the shorter the wavelength of the light that is emitted from it. This simple fact can be used to study the temperature of an object, by observing the colours of light it gives off. You are most familiar with this when you look at a fire: The hottest part of the flame is at the centre and is blue in colour, while the 'cooler' part of the flame is farther away from the centre and is orange/red in colour. So the old saying 'red hot' should actually be 'blue hot'! This spectrum of light emitted as a function of wavelength (colour) is called the blackbody spectrum, and since it is determined only by the temperature of the object, it can be used to extract very accurate temperature measurements of objects under study, if the spectrum itself can be measured. The good news is that the spectrum can be measured. We have constructed an optical system to do just this, but in a manner that is spatially resolved. This means we can measure the temperature of each part of the object very accurately. In our home-built system, we can measure the temperature of the surface of a sample with one degree accuracy and with a spatial resolution of just a few micrometres.

All-optical control

One can extend the use of light from measuring the temperature to actually creating the heating in the first place. If laser light is focused onto an absorbing object, then the absorbed light will heat the object. The advantage of laser heating over conventional oven heating is that lasers allow very intense fields to be created in very localised spots on the object, down to just a few micrometers in size. In a typical laser heating and temperature measure experiment in our laser laboratory, we would focus a high-power laser onto a sample we wish to study, delivering several hundreds watts of average power in a small spot of less than 1 mm in diameter. As the sample heats up, so the temperature rises until a steady state is reached; that is, when the energy being delivered by the laser, matches the energy lost to the surroundings. At any stage in this process we can measure the spectrum of light emitted from the sample, so that we can monitor the temperature rise as a function of time across the whole sample. Thus laser light causes the temperature to rise, and blackbody light allows us to monitor the process; an all-optical temperature control experiment, with no physical contact with the sample. Such a technique can be applied to almost any sample, and has the advantage that the sample can be far away, since the light itself carries the information back to the detector.

We have used our knowledge of laser beams and optics to design novel laser beam shaping optics to change the shape of the light on the sample, by using specially in-house-designed optics that are based on diffraction of light rather than conventional reflection and refraction. These elements have microstructures on the surface to create special laser beams. This, together with creative ways to hold the sample, has allowed us to mimic various boundary conditions in the problem – how the sample is heated, how it dissipates the heat, and ultimately what the precise thermal gradient looks like on the sample. This control is what makes the in-house-designed system unique.

Industrial diamond application

Together with Element 6, leading supplier of high-quality industrial diamond materials, we have used this tool to investigate thermally induced damage in an industrial diamond. The industrial diamond we are studying is used extensively in drills bits for mining, where, due to friction, the diamond becomes very hot. In some cases the diamond starts to lose efficacy. But why? The motivation for the study was to answer the simple question: Can thermal stress alone (ignoring mechanical stress) result in physical or chemical changes to the diamond? Our experimental technique allowed us to tackle this problem in a manner that could not be done before: We were able to localise the effects, by laser-heating a small area, and study the heating under constant temperature and temperature gradient conditions. The results have shown that thermal stress does indeed alter the properties of the diamond, and this can be of a chemical and physical nature. The findings are being used by Element 6 to improve the production of the diamonds by pre-testing new designs against the thermally induced changes. Together with Element 6, we are considering a new project to explain, and then mitigate against, the mechanism that leads to this damage. It is hoped that better insight will lead to better industrial products.

– Prof Andrew Forbes and Bathusile Masina

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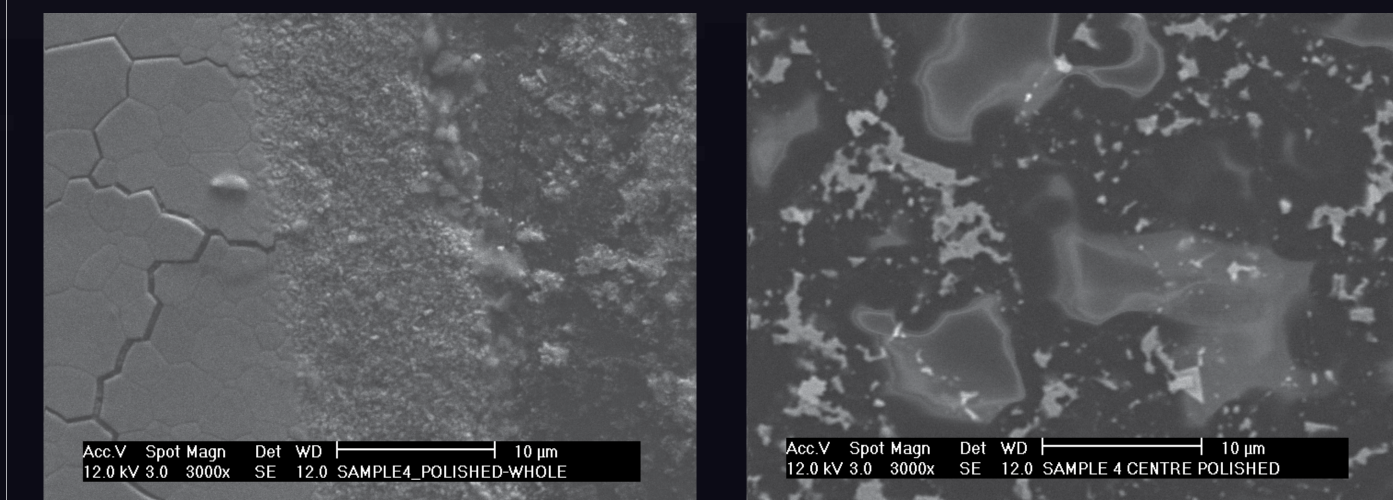
Pictured top is an industrial diamond in good condition, while the two images below show extreme forms of deterioration after laser heating.



Zoomed-in images of an industrial diamond surface after moderate laser heating, showing micro-cracks and other physical changes.

Developing a robotics strategy **for South Africa**

The PackBot robot, used in proof of concept of a mine safety platform.

The Department of Science and Technology has approached the CSIR to facilitate the development of a research, development and innovation (RDI) strategy for robotics in South Africa (Robotics Strategy of South Africa or ROSSA). The draft strategy is now in the finalisation stage, and the strategy is expected to be implemented in the 2012/2013 financial year.

CSIR students working on a mobile robotic platform used for experimental verification.

CSIR researcher Natasha Govender working on a Barret arm during experimental testing of human-machine interface.

THE CURRENT situational analysis of robotics research activities within the National System of Innovation revealed that robotics research efforts in South Africa are fragmented, and lack socioeconomic impact. This is caused mainly by the different research groups in different departments from the same institutions undertaking fragmented robotics research and a lack of a unified robotics strategy at different institutions.

The aim of ROSSA is to provide a unified strategy at both national and institutional levels, and to maximise synergy between the existing research activities in robotics, so as to maximise the socioeconomic impact of robotics research efforts in South Africa.

The draft strategy was developed following an extensive consultative process which included technology end-users, technology developers, the broader South African community, government, and the international robotics society. It was also informed by an analysis of the robotics value-chain.

A value-chain analysis also revealed that in order for robotics to create socioeconomic impact, robotics research must be informed by both domain knowledge and robotics expertise. This is the major reason why current robotics endeavours do not result in visible socioeconomic benefits for South Africa. One of the key success factors of ROSSA should be to bridge the gap between fundamental research and applied research in robotics.

The following main focus application areas of robotics research for South Africa were identified as mining, flexible manufacturing, medical and health care. Other important focus application areas are marine/underwater robotics, defence and security robotics, and agricultural robotics.

The mechanisms of implementing the robotics strategy are still to be confirmed. One of the suggestions is to form clusters based on the focus application area, whereby an organisation with considerable research activity in a specific focus area becomes a leader of a cluster. For example, the CSIR could lead the mining robotics cluster that includes the universities of the Witwatersrand (Wits), Johannesburg (UJ) and Pretoria (UP); Nelson Mandela Metropolitan University (NMMU) could lead the flexible manufacturing cluster that includes the University of KwaZulu-Natal (UKZN), Tshwane University of Technology (TUT), the CSIR and North-West University (NWU); and the University of Cape Town (UCT) could lead the health robotics cluster that includes TUT, Wits and UKZN. Each cluster will then have a strong industry partner. For example, a partner for mining robotics can be the Chamber of Mines, and so on.

The proposed strategic focus areas for the implementation of ROSSA are:

- **Human capital development:** The objective is to create capacity and capability in terms of human capital focusing on the development of scientists, engineers and technicians in the robotics area.
- **Directed and focused research:** The objective is to create a competitive edge for South Africa in focus areas such as mining and robotics manufacturing and fundamental research in areas such as perception, navigation, kinematics and dynamics modelling.
- **Innovation:** The objective is to conduct focused research that will lead to technology diffusion and transfer to industry. ROSSA's research areas shall be determined predominantly by technology pull.
- **Public understanding of robotics:** The objective of this programme will be to share information about the role of robotics in the preservation of jobs and the creation of global competitiveness.

It is proposed that ROSSA be implemented through the creation of the National Robotics Centre, with a mandate of coordinating all the national initiatives in robotics, and developing research and development capacity and capability in accordance with ROSSA.

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Seeing what is invisible to the naked eye

The CoroCAM, here held by UViRCO marketing manager, Riaan Rossouw, is designed to visually display the corona discharges from defects on high-voltage electrical installations.

Visually displaying the corona discharge around a defective, high-voltage electrical installation is a problem that researchers at the CSIR have long since overcome – of that the worldwide success of its CoroCAM designs are proof. The CoroCAM range of products was licensed to UViRCO Technologies, a CSIR spin-out, staffed by ex-CSIR personnel, in 2008.

POWER UTILITIES WORLDWIDE are experiencing pressure to manage their available power efficiently. Preventative maintenance can reduce blackouts and power loss on high-voltage equipment, which results in minimising power losses. Under high load on transmission and distribution infrastructure, localised hot spots limit capacity and can cause black-outs due to failure. Power-loss causes can be minimised through inspection to verify that lines are installed as designed. It is for these inspections that the CSIR-developed CoroCAM has become irreplaceable.

The first CoroCAM was an ultraviolet (UV) imaging camera that could detect and display the UV discharges that indicate high-voltage equipment problems – discharges that are not normally possible to spot with the naked eye as they fall below the range of visible light that humans can detect. This camera could only spot the resulting corona at night and the request soon came for a device that could do exactly the same thing, but during the day.

Four models followed, with the CoroCAM 504 being the current and very popular version with the ability to detect faults during night and day. According to Riaan Rossouw, UViRCO's marketing manager, more than 150 units of the CoroCAM 504 have been sold internationally, the majority of which have gone to China, Russia and the USA.

"However, while the CoroCAM can visually show power utilities and large industrial users of electricity where corona discharge creating equipment faults are located, it cannot show them the severity of the problem. This still requires a human operator," says Rossouw.

UViRCO is about to release the CoroCAM 6D, the latest addition to the CoroCAM family.

The CoroCAM 6D was developed in-house by UViRCO and introduces a number of new features which the market demanded, that is, on-board recording and a simplified user interface.

The CoroCAM 6D leveraged optimised electronics and mechanical design to effect a reduction in production cost.

The technology behind CoroCAM

When looking at an object such as a high-voltage electrical wire through the UV detecting camera, the incoming light is split into two pathways. One path passes the visible light through to a standard video camera which records the images of the object being inspected in order to create a background image. The second path takes its light through a 240-280 nm wavelength solar-blind filter to a camera which is sensitive to UV light.

The UV image is overlaid on the background image to provide a final picture which shows the location of UV corona discharges on the object being inspected.

Other developments

Apart from the CoroCAM, the CSIR, which now acts as research and development (R&D) partner for UViRCO, also developed a product called MultiCAM. This camera can detect both UV and infrared (IR) wavelengths and visually display these images for the easy identification of high-voltage equipment problems.

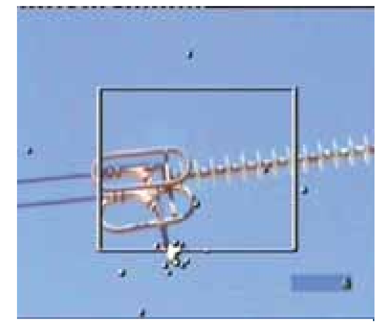
Jeremy Wallis, competence area manager for the sensor science and technology group at the CSIR, says that by adding the IR ability to the UV function, the MultiCAM can show differences in temperature as well as faults that radiate a corona. "Having both the thermal and corona image allows the operator to eliminate possible causes of a problem and get to the real problem (and solution) faster."

With the MultiCAM, an IR dimension as well as the normal visible spectrum can be recorded at the same time as the UV spectrum. The UV image can be overlaid on top of either the IR or background image, showing a final image with temperature differences as well as coronas on the object being inspected.

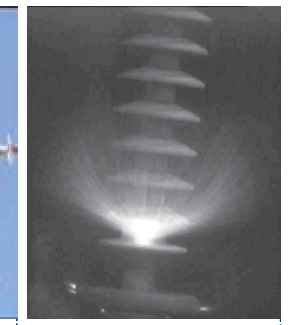
This camera too has been transferred to UViRCO and the CSIR is currently applying for funding to develop a fully radiometric MultiCAM.

– Petro Lowies

The CoroCAM being used at a substation in Russia.



This image, produced by the CoroCAM, shows a typical UV discharge overlaid on a background image.



An image taken with the CoroCAM 111, the best night vision camera. It shows the corona where a cable has been damaged.

The CoroCAM along with an FLIR product mounted inside a gimbal that is attached to a helicopter. Some power utilities find such a gimbal mounting handy especially when inspecting remote cable lines. This allows them to inspect thousands of km of cable in a much shorter time than would have been possible if done manually.

about...

Corona – Corona discharge is an unwanted side-effect of high-voltage electrical installations. It is a phenomenon that results from the ionising of air due to a high electric field. The high electric field gradients form around geometric sharp points such as loose cables, cracks or badly designed equipment.

From polymer technology to cosmetic products

A polymer gel that originated in the CSIR's polymers and composites research laboratories was reinvented to become a highly successful international cosmetic product. The product, called Eyeslices, is commercially available internationally.

EYESLICES is an innovative, cryogel eye pad, which slowly releases active ingredients to the skin to combat a wide range of eye irritations. It reduces the appearance of red eyes, dark circles under eyes, tired eyes, wrinkles and puffy eyes within minutes of use.

It started when CSIR researchers with expertise in polymers invented a water-soluble polymer gel that functioned as a dermal delivery system – in other words, a gel-like substance that could be liquefied and solidified to absorb and emit ingredients to the skin.

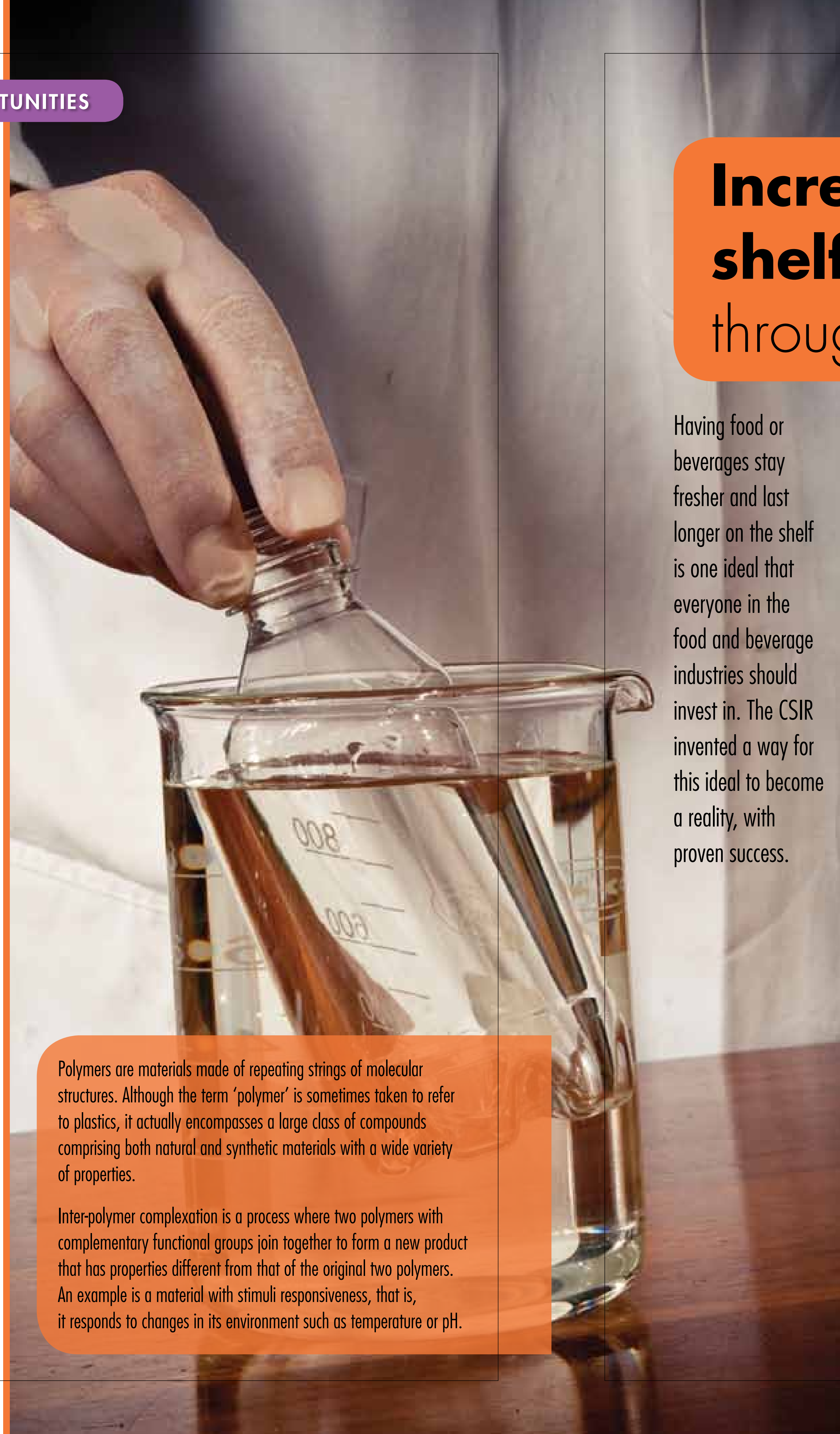
In 2000, entrepreneur Kerryne Neufeldt, licensed this technology from the CSIR and built up a company (i-Slices Innovations (Pty) Ltd) around it. By the end of 2006, the company had stocked the product in over 100 salons and spas in South Africa. The product is now exported to several countries, including Mexico, Australia, the United Arab Emirates and the USA.

The company has received numerous awards for this innovative product, including a Technology Top 100 award in 2007 and a SABS Design Institute Award in 2004. In 2011, the company won the Technology Top 100 award for sustainability.

The product continues to capture market share, with direct response television campaigns marketing the product (under different brands) set to start in the USA in the near future.

– Petro Lowies

Enquiries:
Eyeslices website: www.eyeslices.com



Polymers are materials made of repeating strings of molecular structures. Although the term 'polymer' is sometimes taken to refer to plastics, it actually encompasses a large class of compounds comprising both natural and synthetic materials with a wide variety of properties.

Inter-polymer complexation is a process where two polymers with complementary functional groups join together to form a new product that has properties different from that of the original two polymers. An example is a material with stimuli responsiveness, that is, it responds to changes in its environment such as temperature or pH.

Increased food and beverage shelf-life – A local hero invented through polymer technology

Having food or beverages stay fresher and last longer on the shelf is one ideal that everyone in the food and beverage industries should invest in. The CSIR invented a way for this ideal to become a reality, with proven success.

DURING THE NORMAL COURSE of the research process at the CSIR's encapsulation and delivery research group, new polymer systems with special properties are created. It was the special nature of these newly created polymer systems that led researcher Dr Philip Labuschagne and his team to discover new uses for it. What they found was a very handy new technology specifically geared towards the food and beverages industries.

Their invention, which is now patented, is an oxygen barrier technology. It has the potential to considerably lengthen the shelf-life of food and beverages stored in plastic containers.

Labuschagne explains how the invention happened: "We regularly use a process called inter-polymer complexation in our drug delivery research. The result is a polymeric product with unique properties – one of which is that the polymer has a high density (or a close-knit polymer network formed by hydrogen bonds). This property led us to investigate its effect on the permeability of gasses."

Not letting oxygen through

His group did several trials on various inter-polymer complexation systems until a system was found that reduces oxygen permeability by a factor of about 20 (for polyester-based plastics) and by a factor of around 150 (for polyolefin-based plastics).

"The consequence is that you can increase the shelf-life of any oxygen-sensitive beverage in plastic containers by up to 150 times," he says.

"Another advantage of this technology is that it is a polymer solution that can easily be applied to a plastic surface, such as a beverage container, using a simple dip-coating process. The polymers used are also suitable for pharmaceutical use, thus they are completely non-toxic," he says.

Beverages that are typically sensitive to oxygen are beer or ciders, juices and any tomato-based products. Traditionally these products are stored in glass containers to ensure sufficient shelf-life. However, with this barrier technology, new opportunities for plastic packaging are possible. Plastic packaging is desirable because it reduces the enormous cost (and carbon emissions) resulting from the transport of heavy materials, such as glass.

An external coating

Labuschagne continues: "The coating is applied on the outside of the container using a dip-coating process. Because it has some degree of moisture susceptibility, a second protective UV-curable overcoat is applied over the barrier coating. Both these layers have achieved approval for use as external coating on food containers by the American Food and Drug Administration."

Cost-wise, the barrier technology compares favourably to other barrier technologies, but is superior to them in certain aspects. For example, metal-oxide coatings are expensive and suffer from brittleness; oxygen scavenger technology has a limited life span; and multi-layer technology is not only prone to delamination, but also difficult to recycle. "The containers can also be produced locally which can lead to considerable cost savings," says Labuschagne.

With local inventions such as this barrier technology, it is just a matter of time before we will be able to buy fruit juices that can stay in the fridge for at least a month. Or beer sold in plastic recyclable bottles rather than glass.

"The food processing sector is the country's largest manufacturing sector in employment terms with some 160 000 employees. South Africa has a competitive advantage in a number of fruit and beverage sub-sectors which, if fully exploited, could place it among the top 10 export producers in high-value agricultural products. I believe that the oxygen barrier technology has the potential to improve the competitiveness of this sector," concludes Labuschagne.

– Petro Lowies

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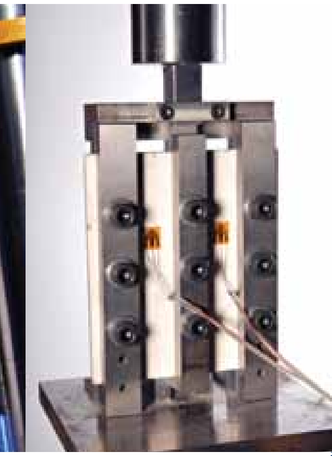
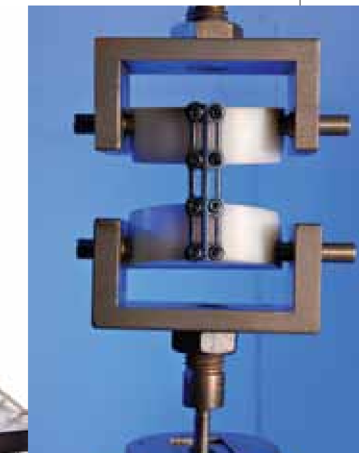
From tensile tests to fracture mechanics: Mechanical testing laboratory leads the way

The composite material used for the Meerkat precursor of the Square Kilometre Array radio telescope (artist impression top) undergoing tensile testing at the CSIR.

Chris McDuling, technical manager at the CSIR mechanical testing laboratory during the testing of an aerospace component



Shear testing of material for South Africa's SKA project (material qualification tests)



Fatigue testing of a titanium vertebrae plate used for biomedial implants

The CSIR's mechanical testing laboratory is a unique South African facility. Not only can this facility provide industry and researchers with both static and dynamic mechanical testing, but it is independent and conforms to international standards.

BEFORE A NEW PRODUCT can be manufactured it is essential to know the properties of the materials to be used. This includes both physical and mechanical properties.

"The CSIR's mechanical testing laboratory was established to provide support to researchers in the evaluation of materials," says Dr Sagren Govender, research group leader of the advanced casting technologies group at the CSIR. "While this is still the case, we have also opened our facilities to industry and have done some interesting work for many industrial partners over the years."

The laboratory is a national facility that has a number of mechanical tests for metals accredited to the ISO/IEC 17025:2005 quality management standard used for test procedures, such as high-temperature and room-temperature tensile tests, high-cycle fatigue testing and strain-controlled, low-cycle fatigue testing. It is also accredited according to the PRO 0430 aerospace standard. All other tests are performed in compliance with the ISO 9001 quality management system.

"All of these accreditations played a role in the laboratory being an approved facility to Airbus, General Electric and Safran. In order to ensure the highest standards are achieved, the laboratory takes part in an international proficiency testing programme administrated by EXOVA in France," explains Chris McDuling, technical manager of the CSIR mechanical testing laboratory.

The CSIR mechanical testing laboratory did tests to qualify the materials used for the dishes of the South African MeerKAT precursor of the Square Kilometre Array radio telescope.

Over a number of years, the range of test equipment has been expanded considerably and procedures for testing composite materials have been developed. An example of recent work in this area is tests done to qualify the materials used for the dishes of the South African MeerKAT precursor for the Square Kilometre Array (SKA) radio telescope.

South Africa's bid to host the SKA telescope includes a locally developed technology with which to manufacture the antennae reflectors on the dishes. The CSIR's mechanical testing laboratory was tasked to determine whether the materials to be used would last the expected 20 years. Since a new manufacturing process was used for the dishes, new test methods had to be developed for the material qualification process for the SKA.

Says McDuling: "Industry benefits from this mechanical testing facility by means of static strength and fatigue testing for the aerospace, power generation, engineering and civil industries. Mechanical properties of turbine blade materials for the aerospace industry and power plants can be determined at this facility. We have also developed advanced testing techniques for high-cycle fatigue testing of reinforcing steel for the construction industry."

In addition, biomedical implant devices are also tested at the facility in accordance with ASTM standards. A number of the devices tested at the facility received approval from the American Food and Drug Administration, which testifies to the laboratory's quality standards.

Some of the laboratory's current clients include Eskom, Sasol, Scaw, Elite Surgical and MegChem.

– Petro Lowies

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MECHANICAL PROPERTIES OF MATERIALS

For structural components, mechanical properties are vitally important, especially for components where safety is critical. Mechanical properties give an indication of how materials perform when subjected to stress and strain and are a function of the materials used and the manufacturing techniques employed to produce a product or component.

High-temperature tensile testing of turbine-blade material

This picture, supplied by the NFTN, was taken at Scaw Metals Group during normal operations.

NFTN now a brand name in the foundry industry

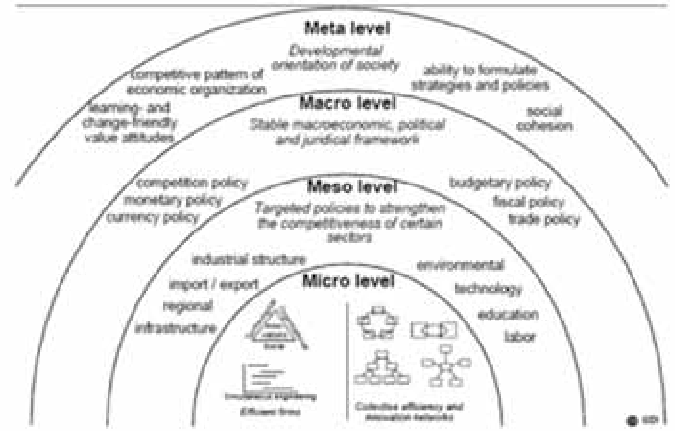
Adrie El Mohamadi, the coordinator of the NFTN, with one of the network's latest products: A guideline for foundries on how to reduce their energy usage and increase their efficiency. The office of the NFTN is based at the CSIR, with administrative operations governed by a Memorandum of Agreement between **the dti** and the CSIR.

It is now close to four years since the inception of the National Foundry Technology Network (NFTN). The vision still remains to increase the global competitiveness of the South African foundry industry through the provision of appropriate services, in order to reduce import leakage, increase local production, and increase investment in the sector. Since the inception of the network there has been substantial progress in all the relevant areas.

AT THE ROOT OF EFFORTS to improve the competitiveness of the foundry sector is the concept of systemic competitiveness. This concept tries to "capture both the political and the economic determinants of successful industrial development"[1]. It refers to a pattern where state and societal actors are deliberately creating the conditions for successful industrial development as systemic competitiveness.

The concept distinguishes between four levels: The micro-level of the firm and inter-firm networks; the meso-level of specific policies and institutions; the macro-level of generic economic conditions; and the meta-level of slow variables like socio-cultural structures, the basic order and orientation of the economy, and the capacity of societal actors to formulate strategies. With this model in mind, all levels of actors within the foundry sector in South Africa were mobilised to identify key challenges causing the industry to be less competitive.

Determinants of Systemic Competitiveness[1]



The challenges identified were:

- Environment regulations;
- Rapidly rising energy cost;
- Access to skills development and training;
- Pricing and reduction of scrap material;
- Technology uptake by industry;
- Sophistication of market segregation; and
- Access to capital.

Actors from all spheres of the economy such as industry, academia, technical institutions and government have joined to form working groups around these challenges, with the aim of improving the overall health of the sector.

The South African foundry sector has pockets of excellence; foundries that are tendering against highly competitive foundries globally and winning these tenders. The NFTN believes that these foundries have a role to play within the sector.

The NFTN now uses the same concept within its support initiatives to foundries by focusing on either a regional or market-specific approach. In doing so, all forms of support can be tailor-made for the needs of the region or sub-sector. The first move between the NFTN and foundries is to conduct a baseline assessment. This assessment identifies possible areas of improvement for the foundry's internal operation. It should be acknowledged that the initiative aims to equip foundries with the means of identifying the need for improvement of their internal operations, and also of their external relations. This includes both inter-firm relationship building and interacting with supporting institutions, especially in training and technology. Through this process the NFTN aims to assist the associations to be more actively involved in industry. The role of the state in enhancing competitiveness and creating locational advantages should be taken into consideration when looking at the South African foundry industry as a whole.

The NFTN sees itself as the oil that keeps the engine running; The health of a sector can only be improved if all the actors are playing their parts.

– Adrie El Mohamadi

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1. Meyer-Stamer, J. 1998, Clustering, Systemic Competitiveness and Commodity Chains: Shaping Competitive Advantage at the Local Level in Santa Catarina/Brazil.

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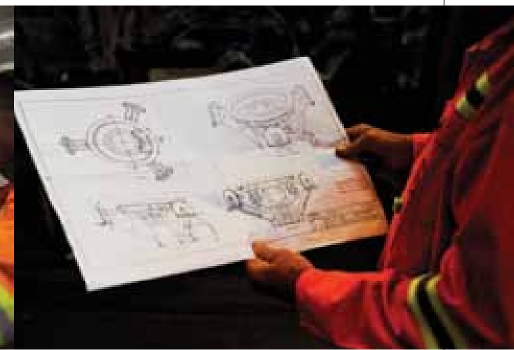
Workers at the Johannesburg-based foundry Wahl Industries, a foundry that specialises in gravity and tilt casting. *Image supplied by the NFTN.*



Thermal image, taken at one of the participating foundries, shows areas of heat loss on an aluminium casting furnace.

Technology assistance programme **has lasting impact on foundries**

To assist South African foundry companies to participate in Eskom and Transnet's competitive supplier development programmes, the Department of Science and Technology (DST) created a Technology Assistance Package (TAP) programme. The CSIR was extensively involved in the execution thereof.

THE TWO STATE-OWNED ENTERPRISES, Eskom and Transnet, have embarked on extensive multi-billion Rand infrastructure-expansion programmes. In the interests of developing and growing the economy, the South African government has developed the Competitive Supplier Development Programme, a localisation initiative aimed at sourcing more of the technology, manufacturing, and expertise required for these programmes locally.

The TAPs for the foundry industry were aimed at addressing the technology gaps in individual companies that must be overcome to better position them as competitive bidders for future infrastructure expansion programmes.

During a benchmarking exercise done in 2009 by the United Nations Industrial Development Organization (UNIDO) and specialist service providers, 28 foundries were identified for technology assistance from the TAP programme. Eventually, 23 of these participated. The CSIR and Mintek were contracted by the DST as technology partners to execute the two highest priority technology areas; the CSIR to support the industry on 'Lean and Clean Manufacturing', and Mintek, on 'Scrap Reduction'.

Identifying needs and implementing solutions

"The TAP took place in two phases," explains Duncan Hope, project manager at the CSIR's metals and metals processes group. "For the first phase, a collaborative approach was followed and a team made up of the CSIR, DST, National Foundry Technology Network (NFTN) and Mintek specialists visited the foundries. We identified specific technology needs, over and above those identified during the benchmarking exercises. It was also a valuable repositioning exercise and the start of longer-term relationships with these companies."

The second phase involved the implementation of technology solutions for the needs identified during phase one. The exercise spanned 18 months.

"We assisted them with a range of interventions, from casting, process simulation and modelling and the installation of shot monitoring systems on high-pressure, die-casting machines, to developing sand foundry component costing software; developing a simple melt quality tester for the aluminium foundries, and fine-tuning a CSIR-developed integrated production monitoring system (SmartFactory) to suit their needs," says Hope. "There were also interventions that involved assistance with getting their waste foundry sand declassified as hazardous waste."

A survey to measure results

A year after the start of the support to the industry, the DST requested that an independent survey be conducted to assess evidence of the impact of the intervention and the current state of the programme. This survey, conducted by the NFTN and the South African Institute of Foundrymen, also provided the DST with a recommendation on whether the programme should continue, and in what format.

All 23 of the foundries responded positively to the continuation of the TAP programme and nine of these foundries were able to report improved process efficiency and productivity as a benefit derived from it. The survey concluded that the TAP programme was a valuable exercise that achieved much more than was expected. It improved the relations between public and private sector and increased the capacity of those foundries which made the most of the opportunity offered to them.

In addition, the survey concluded that it was crucial to realise that this was only the beginning of a very important initiative; that if the momentum was lost, much more than only the beginning of improved productivity, quality and efficiency within the foundries supported would be lost.

"The programme has succeeded in stimulating foundry decision-makers to work towards improved productivity and competitiveness for localisation and exports," says Hope.

– Petro Lowies


Duncan Hope

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John Bryson, Director of KEW Foundries, on participating in the TAP programme[1]:

"KEW Foundries is proud to be a part of this (TAP) programme. Besides the financial implications, the pooling of technology and expertise is something that has been lacking within the foundry industry in South Africa for as long as I can remember.

"Since the launch of the programme, the company has managed to address various short-term challenges relating to the casting of larger diameter solid sheave wheels, thereby minimising the necessity for the smaller half-rim assemblies, which will ultimately reduce machining times and associated costs.

"As part of the Technology Localisation Programme, KEW Foundries is supplying castings, material for testing, technical specifications, foundry process knowledge, as well as other technical input and time. We are also highlighting the positive nature of this initiative and encouraging participation by more and more industry members."

1 From a KEW Foundries media release, January 2012

A demonstration of how an infrared imaging camera can be used to detect heat leakage and hot spots in energy-intensive systems. Energy remains a critical resource for South Africa and an industrial energy-efficiency project was introduced in 2010 in a drive to improve energy usage practices.

Resource efficiency and cleaner production for advanced manufacturing

With current trends in global economic growth as well as population growth, environmental degradation is on the increase with both waste and pollutants being released faster than the Earth can absorb them, and natural resources being consumed faster than they can be restored. New innovative patterns have emerged to reduce environmental stress and the National Cleaner Production Centre of South Africa (NCPC-SA), through its resource efficiency and cleaner production (RECP) assessment process, recommends clean production technology as a cost-saving option, in addition to other low-cost, no-cost options.

THE TARGET is to drastically reduce the environmental footprint and increase the competitiveness of industry by 'doing more for less'.

Advanced manufacturing involves, among other things, the introduction of new or more efficient technologies, as well as the generation and management of knowledge. RECP is one of the very latest methodologies aimed at improving productivity and optimising plant operations. It focuses on improving resource and energy efficiency by introducing more efficient technologies and enabling solutions along the value chain, thus supporting long-term sustainability in terms of global competitiveness, ecology and employment.

The NCPC-SA is a key industrial sustainability programme of the Department of Trade and Industry (**the dti**). Hosted by the CSIR, it utilises RECP to address the country's critical need to increase global competitiveness, while reducing resource and energy inefficiency and the environmental impact of industrial activities. In-plant assessments are undertaken at participating companies to identify areas for efficiency improvement in terms of energy, water and raw material usage.

"The activities of the NCPC-SA are aimed at strengthening market access for South Africa's industry, fostering networks and transferring RECP technologies and services; contributing to the sustainability of industry value chains, and delivering measurable economic, environmental and social impacts," explains NCPC-SA Director Ndivhuho Raphulu. A total of 162 cleaner production assessments were undertaken between 2009 and 2011, yielding potential savings of approximately R78 million. Besides the financial, environmental and technical benefits, a more consistent product output quality was also achieved, while the working environment in participating plants improved substantially.

The services of the NCPC-SA are fully subsidised at this stage, and are made available to participating companies at little or no cost, to enable industry to proactively comply with competitiveness and efficiency policy, as well as regulatory frameworks and standards before these become legislated.

The centre currently focuses on eight priority sectors identified in government's Industrial Policy Action Plan for 2010 to 2013 (IPAP2) as key to job creation, economic growth and market competitiveness: Agro-processing; automotives; chemicals, plastic fabrication, cosmetics and pharmaceuticals; fibres, textiles and clothing; pulp and paper; hospitality and tourism; and metals, and capital and transport equipment. It also addresses the green industries sector, which includes waste recycling/remanufacturing and commercial buildings.

Energy efficiency

Energy remains a critical resource for the country. The industrial energy-efficiency improvement project was introduced in 2010 to contribute to the sustainable transformation of energy usage practices in South African industries, and enhance national energy security, while promoting job creation and reducing carbon dioxide emissions. The project seeks to actively involve a number of key industries identified for their potential to bring about significant reductions in the overall energy consumption of the country. The first seven of an envisaged 25 leading medium to large companies are currently pioneering the implementation of energy management systems within their operations as a means of increasing profitability. A further participation option involves becoming a demonstration plant where the measurable and verifiable impact of recommended energy systems optimisation interventions may be showcased. The focus is on energy-intensive systems such as steam, compressed air, pumps, motors, process heating and fans.

The project is a collaborative initiative between **the dti** and the Department of Energy, the Swiss Secretariat for Economic Affairs and the United Kingdom Department for International Development. The United Nations Industrial Development Organization (UNIDO) is the implementing agent.

Small, medium and micro enterprises (SMMEs) in the manufacturing sector also benefit from the project through subsidised energy audits aimed at raising awareness of the benefits of energy-efficiency practices.

Capacity building

The availability of suitably skilled human resources is essential to the implementation and sustainability of RECP methodologies and techniques in industry. To address this need, the centre facilitates the presentation of training workshops by internationally acknowledged experts for representatives of the environmental goods and services sector, as well as from industry and government institutions. RECP training workshops are presented across the country at least once a year, while more than 1 000 consultants and representatives of companies and government have undergone various levels of training in the areas of energy management systems and energy systems optimisation since August 2010.

The NCPC-SA also runs a sustainable entrepreneurship programme involving the placement of postgraduate students in companies. These companies benefit from the availability of trained and dedicated resources in addressing specific competitive gaps and/or environmental constraints, while students gain valuable cleaner-production experience in the workplace.

During the past year, the centre introduced a clean technology accelerator programme for SMMEs and entrepreneurs to leverage new and innovative technologies, with particular emphasis on energy efficiency, renewable energy and green buildings. The objective is to stimulate green entrepreneurship, create more jobs, and contribute to the sustainability of new eco-efficient enterprises. The first round of winners was announced at a gala event in Durban during COP 17.

Barriers to implementation

Financial considerations and the local availability of relevant technologies are key barriers preventing full implementation of RECP recommendations, which is required to maximise the cost-savings benefits of RECP. To address this, government is finalising a suite of incentive schemes, which companies that adopt cleaner production as a tool to improve efficiency and competitiveness can apply for. This includes a tax rebate, a scheme to support the implementation of energy-efficiency measures, and the soon-to-be-announced manufacturing competitiveness enhancement programme (MECP) of **the dti**.

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"Greener production methodologies and technologies have a direct and positive impact on the bottom line of a company."
– Ndivhuho Raphulu, Director: NCPC-SA

Capacity building is a key focus of the industrial energy-efficiency project. Training workshops on energy management systems and energy systems optimisation – ranging from pumps to fan systems – are presented by international experts at advanced user and expert level. Pictured is the first South African group of expert-level trainees on fan systems during the on-site practical session at SAB Maltings. From left are USA-based trainer Ron Wroblewski; Alfred Hartzenburg, NCPC-SA; Erik Kiderlen, Ashway Investments CC; Bill Cory, UNIDO; Eddie Raad, CFW Fans; Hamied Mazema, UNIDO; Azeem Mohamood, Saint-Gobain Construction; Jaco Kirstein, SAB Ltd; and Darrin McComb, Resource Innovations.

Seeing South Africa through a manufacturing LENS

Africa's first laser-engineered net-shaping system

The CSIR has strengthened its ongoing support for industries such as automotive, manufacturing, health and defence, by acquiring Africa's first laser-engineered net shaping (LENS) system.

THE LENS SYSTEM differs from the other approach to laser-based additive manufacturing, known as selective laser sintering (SLS) or melting (SLM). Both technologies build parts layer-by-layer from a sliced computer-aided design (CAD) model by employing a focused laser beam to melt and consolidate material, which is supplied in a powder bed.

By contrast, the LENS system feeds blown powder from a nozzle into a laser-generated melt pool, which is then translated over the area, which corresponds with the CAD model layer. The LENS and SLS processes complement each other. While the SLS process offers better surface quality and more intricate part geometry, the LENS process offers faster building rates, larger parts and easy variation of alloy composition for functionally graded materials.

Another advantage of the LENS system is the ability to perform high-quality repairs of original components; it enables the damaged part to be put back into service, which is obviously of great interest to local end users. The LENS system not only offers a fast, high-quality repair option, but also in many instances makes it possible to refurbish the part in such a way that it will have a longer service life than the original. In addition, the low-heat input and rapid-cooling rates guarantee low distortion of components and superior material properties, resulting from rapid solidification and consequential grain refinement.

The CSIR, through its laser material processing group, is committed to supporting the South African manufacturing industry through targeted, application-oriented research and development, to improve its global competitiveness as a primary driver of wealth creation, economic growth and a better life for all South Africans. The LENS system will make a major contribution towards achieving this goal, since it also addresses priorities such as the establishment of aerospace and titanium industries.

Refurbishment of industrial components is particularly important in the South African context. South Africa's manufacturing industry relies on imported equipment and critical spares have to be kept in stock or be imported. Where high-value parts are involved, manufacturing companies have to choose between expensive spare-part inventories or the possible loss of production due to downtime while spare parts are being imported. The LENS system offers a cost-effective alternative in terms of the repair of components, and perhaps even 'building' a complete spare part.

It uses a high-power laser (500 W to 4 kW) to fuse powdered metals into fully dense three-dimensional (3D) structures.

Technical make-up

The LENS 3D printer uses the geometric information contained in a CAD solid model to automatically drive the LENS process as it builds up a component layer-by-layer.

Additional software and closed-loop process controls ensure the geometric and mechanical integrity of the completed part.

The LENS process is housed in a hermetically sealed chamber which is purged with argon so that the oxygen and moisture levels stay below 10 parts per million. This ensures that the material properties of components built from highly reactive materials like titanium are not compromised by the presence of oxygen in the deposited material. The metal powder feedstock is delivered to the material deposition head by a powder-feed system, which is able to precisely regulate mass flow. The result is 3D parts of high quality and integrity.

The LENS system can build parts – such as turbine blades and hip implants – with the aim of tailoring its properties or simply repairing an area that has been damaged through corrosion or wear. The advantage over traditional methods is the low-heat input that eliminates distortion and the ability to create functionally graded materials (which can control the metallurgical properties).

The CSIR offers companies a once-off opportunity of refurbishing a component with the LENS system, to demonstrate its capabilities (i.e. bore cladding, 3D cladding) at no charge.

(Also read the article on pages 12 and 13.)

– Mzimasi Gcukumana

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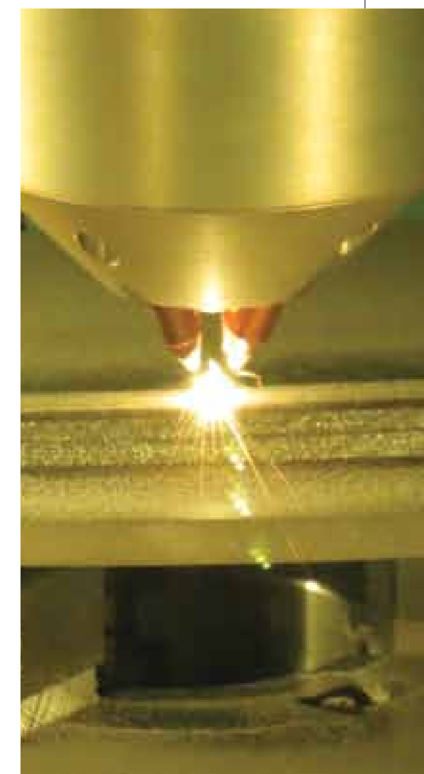

The new LENS system

Laser-based manufacturing support programme **for SMMEs**

The South African economy is growing at a rate in excess of 4% per annum with manufacturing as a key component. Unfortunately, an economic growth rate of 4% is not nearly enough to provide the number of jobs required by the South African economy. This can be deduced from the ever-increasing unemployment rate, especially among 15 to 25 year-olds. Overall unemployment is in the order of 25 to 30%. Job creation requires new industries, which are best established through small, medium and micro enterprises (SMMEs), and which in turn are created through technological innovation. Laser technology is a key enabler in this context.

THE NEED to become and remain globally competitive through enhanced productivity, facilitated by advanced technology, is widely appreciated. Often these technologies – particularly those that are laser-based – are not readily available because they originated abroad or are too expensive for small enterprises. With the downturn in the economy, any additional advantage that can be supplied to the South African manufacturing industry is imperative. In the field of lasers, the CSIR has worked with SMMEs over the past 10 years in an attempt to help them become more competitive. The CSIR's laser materials processing group, through its capabilities in laser manufacturing processes, is well positioned to assist the local manufacturing industry, and in particular the SMME component, to reduce the entry barriers to utilising laser-enabled manufacturing solutions. The group has well-established technology platforms; housing equipment that is unique in South Africa, complemented by a team of highly trained and experienced scientists, engineers and technicians. The equipment includes South Africa's only:

- Laser-cutting facility capable of processing three-dimensional sheet metal profiles
- High-power laser welding research and development (R&D) facility
- Laser metal deposition (build-up of volumes)/laser surface cladding R&D facilities.

Over the past three years, the CSIR's laser material processing group has supported, on average, 20 short technology feasibility studies for industrial companies per annum. It is estimated that more than 60% of these studies have resulted in the adoption of a laser-based technology solution by the company concerned.

In some cases companies were able to adopt and integrate new manufacturing processes with their existing technology and infrastructure. In addition to assisting SMMEs, the CSIR has assisted companies such as Bell equipment and Werma Automotive tooling, that needed limited production services, through existing manufacturing capacity. In a third mode of technological collaboration, the CSIR has worked with clients, for example, Denel Munitions, to acquire appropriate equipment and implement an integrated manufacturing solution.

In cases where no off-the-shelf technology solutions are available, the CSIR is capable of designing and constructing a laser-based technology solution for transfer to the client. Work has been undertaken in this mode for Tappo Industries, Robert Bosch South Africa, Myriad Plastics and Eskom.

With these manufacturing support efforts, the CSIR is collaborating with organisations such as the Aerospace Industry Support Initiative to create the laser-based manufacturing (Labama) support programme. The aim is to empower SMMEs that are active in the aerospace industry, with laser-enabled manufacturing solutions so that they can become more competitive in the global market and provide services to the aerospace industry. Through this programme, SMMEs can either improve existing capabilities or expand into new areas. The CSIR's laser material processing specialists will guide SMMEs in arriving at an appropriate solution that enables them to succeed on their own.

– Federico Sciammarella

Tappo Industries is an example of an SMME that has greatly benefited from a laser-based solution and is now a global player (see opposite page). Mark Luksich, maintenance manager at Tappo, is flanked by company machine operators, Kagiso Phiri ,left, and Johanna Mashiane.

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CSIR lasers solve backlog challenges at Tappo

TAPPO INDUSTRIES was started 22 years ago and supplies various motor industries and paint shops with over-locked cloths and tack rags. The introduction of laser technology at this medium-sized enterprise, strategically positioned among car component suppliers at the Automotive Supplier Park in Rosslyn, Pretoria, has seen the company drastically improve its productivity.

The company supplies automotive companies with lint-free cloth – a specialised wiping cloth designed to remove loose particles of dust and dirt that contaminate a surface that is to be painted, coated, laminated, or otherwise finished. It also manufactures antistatic garments for clean-room environments. The company cuts about 900 m of cloth every day – an impossible feat prior to employing CSIR-developed laser technology.

According to Mark Luksich, maintenance manager at Tappo, the company came under pressure to meet the rapidly increasing demand for its products. When, in 2001, it reached the point where Tappo could no longer meet the demand with its production based on manual labour, Tappo approached the CSIR for a solution. "We wanted to automate our processes and laser technology was the only way to do that," recalls Luksich.

He says that deliberations took place between the two organisations, focusing on how best the CSIR – with its vast knowledge and expertise in lasers – could integrate this technology in Tappo's manufacturing processes. "We provided the CSIR with specifications and the organisation delivered the project according to our specifications and on time."

Laser cutting can improve both production and quality. In addition to improved productivity, Tappo now has the advantage of a sealed cut edge with no residual lint. The previously used manufacturing technology employed a mechanical cutting process, which caused unravelling of the materials, resulting in small fibres, or lint that are left behind on the car bodies after they have been wiped, in preparation to be painted. Residual lint on the car body results in flaws in the paintwork.

"The laser technology has improved our turnaround time and has enhanced our productivity," Luksich comments. Previous processes were cumbersome and extremely slow. The laser cutter freed up our workforce from cutting and we use them elsewhere," he remarks.

Based on the good relationship between the two organisations, Tappo signed a service agreement for maintenance with the CSIR.

"Tappo Industries is an excellent example of the impact that laser-based manufacturing can have on the profitability of a company," says Hardus Greyling, operations manager at the CSIR National Laser Centre.

– Mzimasi Gcukumana

Machine operator Johanna Mashiane of Tappo Industries lays out the lint-free cloth for laser cutting.