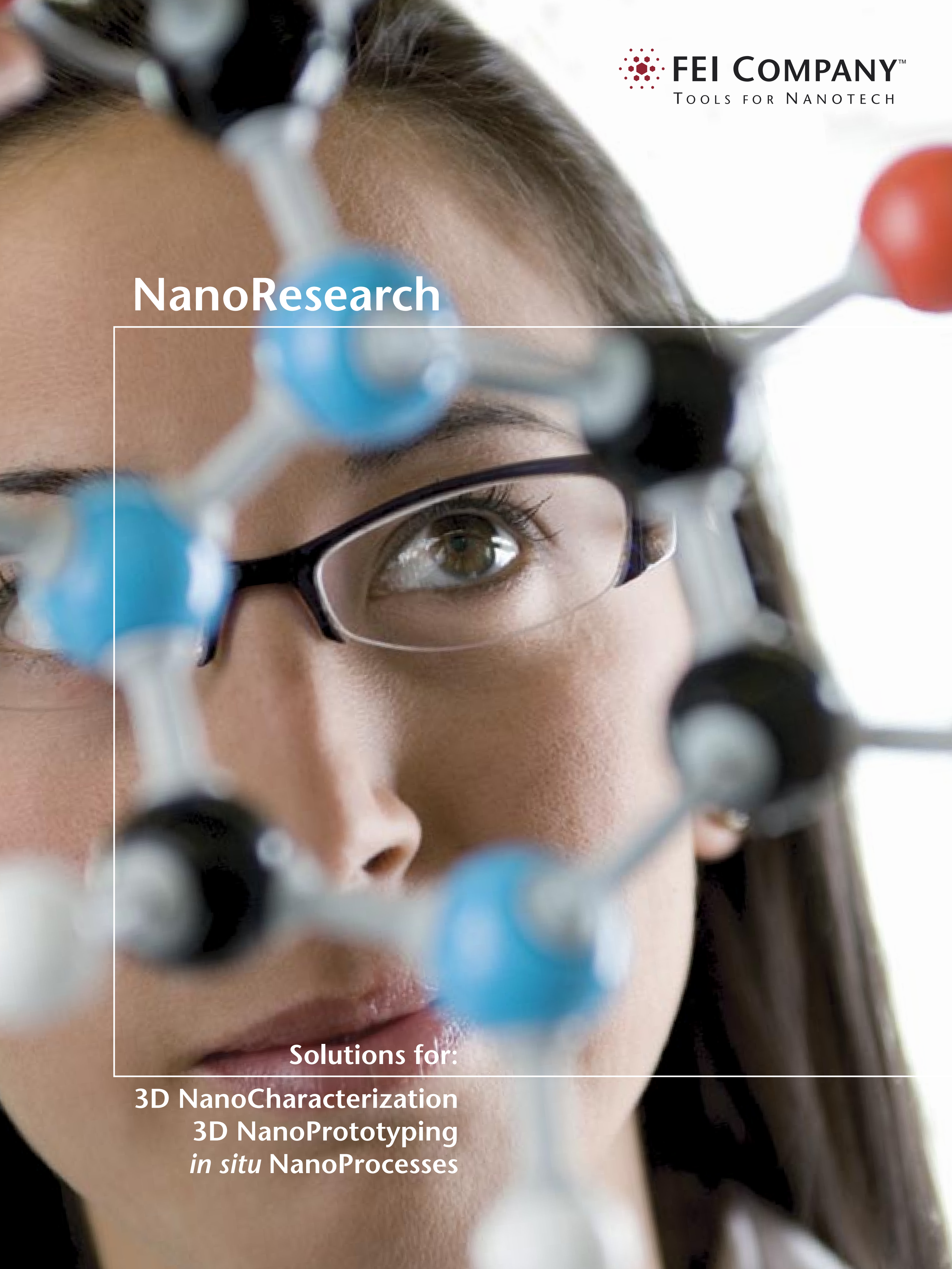


FEI COMPANY™
TOOLS FOR NANOTECH

NanoResearch

Solutions for:

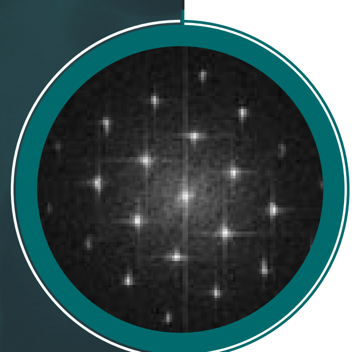
3D NanoCharacterization
3D NanoPrototyping
***in situ* NanoProcesses**

Nanotechnology – beyond the state-of-the-art

Much that occurs in the macro-world of our everyday experience is ultimately determined by processes and phenomena that operate on the nanoscale – the scale of individual atoms and molecules, and the forces that act between them. This realization itself is not new. What is new is the growing collection of tools that allows us to explore and manipulate our world at this fundamental scale – Tools for Nanotech™. This realization, these tools, and the creativity and ingenuity of individual researchers and their organizations together constitute the nanotechnology revolution.

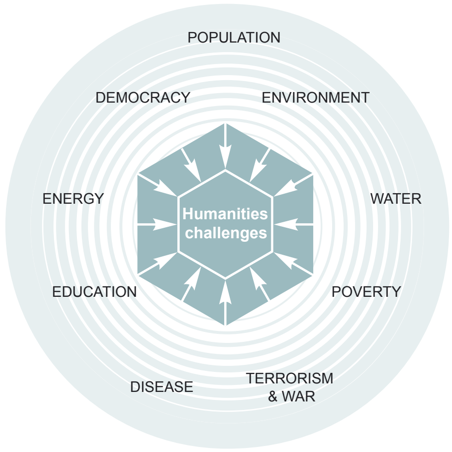
Research in nanotechnology is in the midst of a critical transition, from a discovery driven process in which the majority of new products are the serrendiptous result of investigations into fundamental properties and behaviors at the nanoscale, to an application driven process, 'nanomaterials by design', in which new products are developed to meet specific requirements based on an understanding of the fundamental processes. As development activity moves into an industrial setting, researchers will demand tools that deliver not only state of the art performance, but also reliability, usability and economic efficiency – qualities for which FEI is well known across a broad range of industries including semiconductors, data storage, mining, forensics, chemicals and materials.

Nanotechnology has the potential to impact nearly every aspect of our daily lives. Practical applications already exist, from stain-resistant fabrics to scratch-resistant automotive coatings, but these are only the beginning. Researchers are exploring new applications in chemistry, materials, space, energy, information, communication, transportation, and conservation. Some of these new applications will create new industries or radically change existing ones. New industries will create new economies, may pose new dangers or opportunities, and ultimately reweave the very fabric of our societies.



Our future is driven by your challenges

Nanotechnology is a broad term – some might say too broad – and its breadth creates a unique set of challenges for those who would work there. It is by nature multidisciplinary, and success requires collaboration across traditionally separate fields of knowledge. At FEI Company we embrace this collaborative model at every level. It shapes our organization, directs our research, informs our new product development, designs our facilities, and directs our communications. One example is our network of 'NanoPorts', expressly designed to seek out opportunities to work with our customers to understand and solve their research problems. At the other end of the scale, in the design of hardware and software, we strive to incorporate networking, communication and data sharing capabilities at every level.



Dr. Richard Smalley, 1996 Chemistry Nobel prize winner, first started to relate nanotechnology with challenges facing humanity. The figure above names key problems and challenges of today's society that could be improved or solved with the use of nanotechnologies.

At FEI we make the invisible visible – so that your work advances and your organization succeeds

We are FEI Company

At FEI we know that our success depends on yours, and you, in turn, rely on the quality and reliability of the tools we provide. The nano revolution is still young, and though its promise is widely recognized, so too are its risks. Successful execution on early opportunities can provide huge rewards, but such enterprises are fraught with uncertainties and there are plenty of competitors waiting to capitalize on mistakes. The selection of your most fundamental tools will be among the most important decisions you will make.

Of course the tools you select must provide the best possible performance against the criteria you define today, but equally important they must have the flexibility and expandability to address the requirements you won't discover until tomorrow. No system that you buy today can possibly accommodate all possible future needs. So, in choosing a system you are also choosing a partner, one that you will need to rely on for the life of the instrument, not only to support its current capabilities but also to develop new capabilities to address needs that are as yet unknown.

Our desire to meet future needs does not reduce our commitment to current needs. Quality and reliability are built into our products at every level and our global service organization is second to none. We offer extensive training programs that range from basic operation and maintenance to advanced technique and collaborative methods development.

We are FEI Company

We make Tools for Nanotech – scanning and transmission electron microscopes (SEM and TEM) and focused ion beam (FIB) systems – that allow you to visualize, analyze and manipulate your world at the nanoscale. We are a global technology company with more than 6 decades of leadership in imaging and analytical instrumentation. Throughout that time we have been pioneers in our chosen technologies, introducing one of the first commercial TEMs in 1949, and the first DualBeam™ (FIB/SEM) system in 1993. Our new Titan™ family of S/TEMs offers the best imaging resolution available today, as good as 0.5 Ångström, sufficient to resolve individual atoms in many materials.

We are determined to continue to lead our industry and we know that to do so we must nurture and maintain relationships with leading scientists and research organizations among our customers. The knowledge network that this approach creates is a resource that works both ways, providing us with an awareness of current and future needs in the research marketplace, and our customers with access to knowledge and solutions across a broad range of applications. Together with our customers we strive to be thought-leaders, offering creative and innovative solutions that will drive the continuing development of nanotechnology.

NanoPort

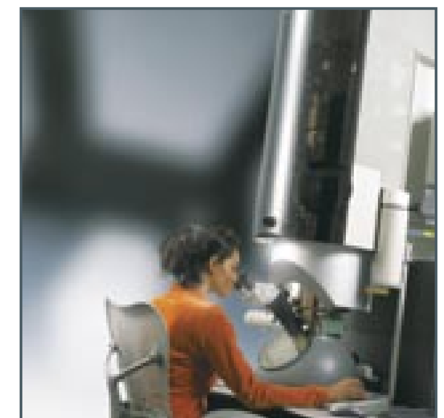
FEI's unique NanoPorts, located in the Netherlands, the United States, and Japan, are tangible evidence of our commitment to customer-centered collaboration. They provide a direct conduit for customer involvement in our development, engineering, training, testing and demonstration activities.

Continuous innovation

Technology waits for no one. Our desire to play a leading role in the development of nanotechnology requires that we embrace a culture of continuous innovation. The leading edge of a revolutionary technology is not often a comfortable place to be, but a willingness to accept risk is the ante to play in this high-stakes game. Breakthrough results are seldom discovered along a well trodden path.

Our new Titan S/TEM family, which offers unprecedented improvement in image resolution, is a case-in-point. Though the aberration correction technology that underlies the improvement is well known, FEI alone took the risk of incorporating it in a new TEM. As a result the Titan offers directly interpretable image resolution 2 to 3 times better than uncorrected TEMs.

As is often the case, innovation begets innovation. The incorporation of aberration correctors permits the design of larger lenses which in turn allows room for new technologies that maintain or control the sample environment. We can use this freedom to expand the types of samples and in situ procedures possible in an electron microscope. We want to relieve the researcher of the burden of adapting the sample to the microscope – instead, adapting the microscope to the sample.



Titan 80-300

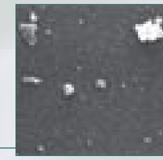
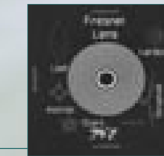
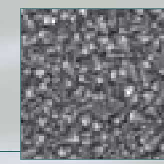
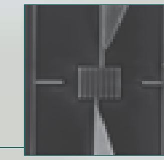
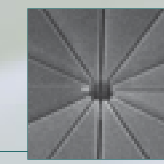
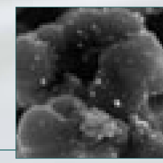
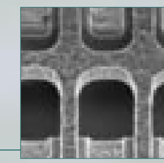
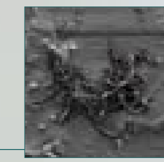
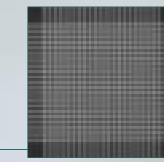
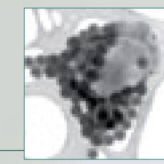
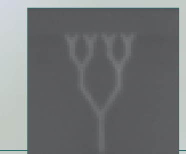
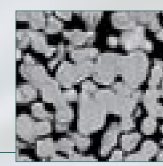
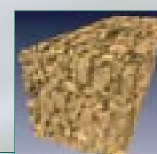
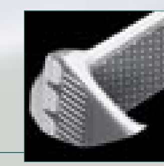
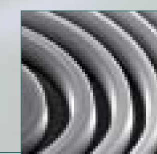
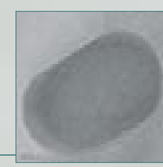
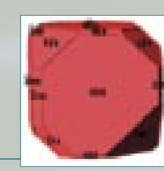
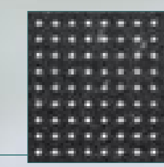
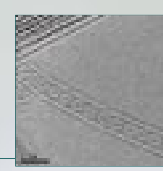
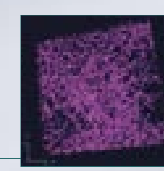
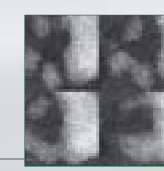
The Titan microscope incorporates a newly designed platform dedicated to the principles of ultimate stability, ultimate performance and ultimate flexibility for corrector and monochromator technology and its applications.

FEI's tools for NanoResearch

FEI tools deliver critical capability in three essential application categories:

- **2D and 3D NanoCharacterization**
- ***in situ* NanoProcesses**
- **3D NanoPrototyping**

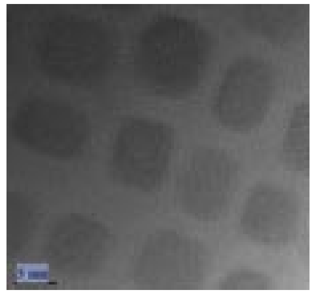
- SEMs like the Quanta™ FEG can visualize surface topography with a resolution of 1 - 2 nm resolution over an extended range of in-situ environmental conditions
- The Nova™ NanoSEM 30 improves on the resolution of the SEMs by using an 'immersion' type objective lens
- The new Magellan™ 400 SEM is the first SEM to offer subnanometer resolution over the full 1 kV to 30 kV electron energy range, effectively establishing a new performance category known as XHR SEM. Its extraordinary low voltage performance provides extreme high resolution, surface specific information that is simply unavailable from other techniques
- Quanta 3D FEG is the most versatile high resolution, low vacuum SEM/FIB for prototyping and sample manipulation
- Helios NanoLab™ is the next generation DualBeam combining subnanometer SEM resolution with high performance FIB for the highest precision in thin sample preparation and prototyping
- Tecnai™ TEMs are research grade instruments that offer sub-Ångström information limits in a wide variety of lens configurations
- The Titan S/TEM family offers aberration correction for directly interpretable, sub-Ångström image resolution

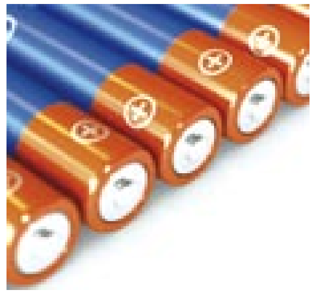
		NanoCharacterization	3D NanoCharacterization	*in situ* NanoProcesses	3D NanoPrototyping
SEM/ESEM	Quanta FEG series	 High magnification SE image (high vacuum) of a TiO_2 powder, co-doped with a small quantity of platinum, obtained by the sol-gel process.	 Low voltage BSE image (deceleration mode in high vacuum) of a TiO_2 powder obtained by the sol-gel process.	 *In situ* study of 'local' wetting behavior on surfaces using direct fluid injection in ESEM mode.	 Nanostructures created by using electron beam lithography.
	Nova NanoSEM 30 series	 High contrast compositional and topographic characterization in high and low vacuum.	 Low vacuum environment actively avoids sample contamination and allows unprecented imaging.	 Characterizing electrical properties *in situ* using a 3-probe station.	 Electron beam lithography: 40 nm lines written in 400 nm thick PMMA.
	Magellan family	 Low voltage surface analysis of platinum catalyst nanoparticles. The size of the particles is between 5 nm and sub 1 nm.	 XHR SEM application, where a deprocessed sample has been stripped back to the poly-silicon level. *Courtesy of ST Microelectronics Malta/Grenoble, France.*	 High resolution low voltage image of nanotubes obtained using beam deceleration and effective landing energy of 200 eV. *Courtesy of Prof Raynald Gauvin and Camille Probst, Ph.D. Student, McGill University, Canada.*	 Electrostatic beam deflection and a conjugated blanker enable electron beam lithography with high writing speed and great linearity.
SEM-FIB	Quanta 3D FEG	 FIB cross-section showing inclusions in an aluminum matrix.	 Volume-rendered reconstruction showing the distribution of inclusions in an aluminium matrix.	 STEM-in-ESEM system enables *in situ* measurment of the distribution of latex spheres in a dispersion.	 Nanofluidic channels milled in quartz using Quanta's automated drift suppersion control software, enabling accurate milling of complex structures in non-conductive samples.
	Helios NanoLab	 Cross-section through a bulk sample of silicon carbide. *Sample courtesy of Dr. D. Bernard, ICMCB, France.*	 3D reconstruction showing sintered silicon carbide. *Sample courtesy of Dr. D. Bernard, ICMCB, France.*	 Advanced and flexible sample preparation capabilities are demonstrated by this plan-view preparation on an DRAM.	 Fresnel zone plate lens milled in silicon by direct FIB patterning, demonstrating advanced leading-edge and redeposition control.
TEM/STEM	Tecnai G^2 series	 HR-TEM on precipitate in aluminium matrix. The nature of the interface can be determined down to the atomic level.	 Electron tomography reveals the relationship between crystal facets.	 Manipulation of iron nanoparticles with nanotube. *Reproduced with permission K. Svensson, H. Olin and E. Olsson, Phys. Rev. Lett. 93 (2004).*	 Electron beam-induced deposition (EBID) of nanostructures on 10 nm thick carbon foils, using $W(CO)_6$ as a precursor gas. *Courtesy of W.F. van Dorp, C.W. Hagen, and P. Kruit , Delft University of Technology (Netherlands) and P.A. Crozier, Arizona State University (Tempe, AZ).*
	Titan family	 Atomic resolution HR-TEM image of a single wall carbon nanotube filled with carbon 'Bucky balls' acquired at 80 kV. *Courtesy of Prof. N.Kiselev, Institute of Crystallography, Moscow, Russia.*	 Electron tomography enables 3D visualization of nanonetworks. *Courtesy of Dr. Joachim Loos, Eindhoven University of Technology, Netherlands.*	 HR-STEM images of heat induced movement of platinum atoms on surface.	 Imaging twin boundries of a gold nanobridge using C_s-correction at 300 kV.

3D NanoCharacterization

The latest SEM, DualBeam, aberration-corrected and monochromated S/TEM imaging and spectroscopic capabilities already give outstanding performance, but nanocharacterization moves to an altogther new level with 3D techniques. DualBeam technology combines electron and ion beam processing and imaging that affords 3D visualisation down to the nanoscale, while S/TEM tomography goes beyond the state-of-the art with 3D reconstruction at the nanoscale and the possibility to go down to the atomic level. And it doesn't stop there. Analytical techniques such as electron backscatter diffraction (EBSD), x-ray microanalysis (EDS) and energy filtered TEM (EFTEM) can all be extended to three dimensions, giving a world of new information on the inter-relationships between heterogeneous media.

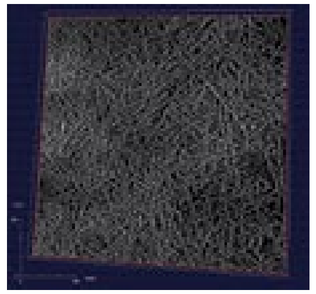
Structure/property | **Function**

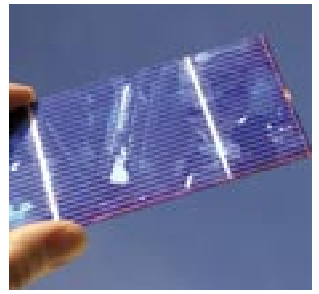




2D and 3D investigations of cerium oxide nanoparticles give new perspectives on their effectiveness in solid oxide fuel cells. Reproduced with permission: Kaneko *et al* (2007) *Nano Letters* **7** (2).

Structure/property | **Function**



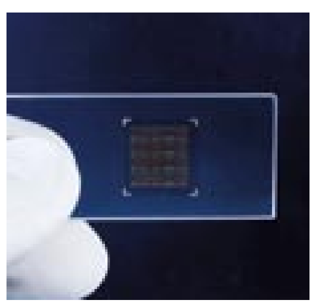


3D studies of semi-conducting polymers help our understanding of the function of organic light emitting diodes and solar cells. Courtesy of Dr Joachim Loos, Eindhoven University of Technology, The Netherlands.

3D NanoPrototyping

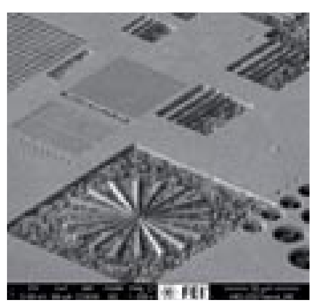
Nanoprotyping is a fast, simple way to design, fabricate and test small-scale structures and devices using either an electron beam or focused ion beam to modify the specimen, and involves site-specific milling, lithography or chemical vapor deposition at the nanoscale. The combination of world-leading optics, high-precision beam patterning, accurate stage movements and the widest range of gas injector processes available add up to the delivery of high-quality 3D nanoprototyped structures. User-friendly protocols and software, built on a wealth of experience, help to give rapid, repeatable results, even for the most challenging substrates.

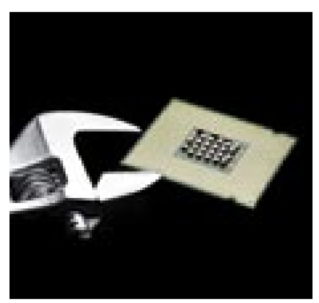
Structure/property | **Function**



A split-ring resonator 3D nanoprototype, FIB-milled (in a magnetic metamaterial). These structures are of importance in the design of photonic devices and other advanced nanotechnological applications.

Structure/property | **Function**



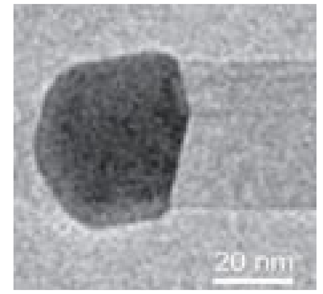


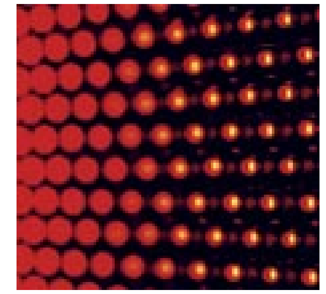
Nanolithographic processing of materials. Facilitates the fabrication of devices with ever-decreasing dimensions.

In situ NanoProcesses

The electron microscope has truly evolved into a lab in a chamber. ESEM, DualBeam and ETEM technologies allow the introduction of gases and, with a variety of stages for heating and cooling (plus micromanipulators and injectors for ESEM and DualBeam), this potentially allows a host of *in situ* processes to be investigated, including those at the atomic level. This opens the way to the development of a more fundamental understanding of chemical and physical phenomena, helping us to visualise and correlate the structure, property and function of materials as they undergo processes such as catalysis, oxidation, reduction, polymerisation, deformation, thermally induced phase transformations and much, much more.

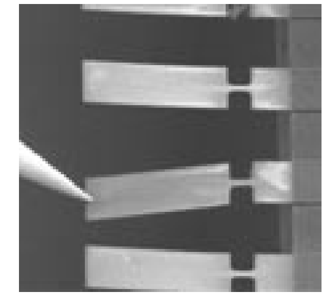
Structure/property | **Function**

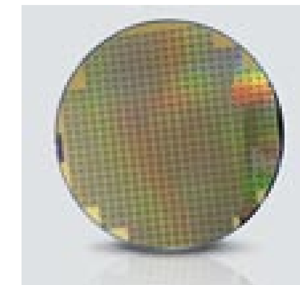




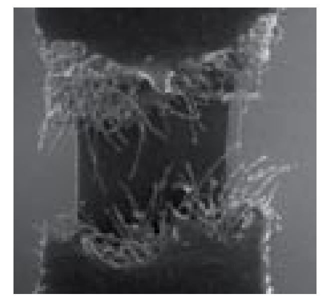
Chemical reactions, like the synthesis of this silicon nanowire, can be initiated and followed in situ, crucially augmenting our knowledge of many industrially relevant systems. Courtesy of Hofmann *et al*, Cambridge University, UK.

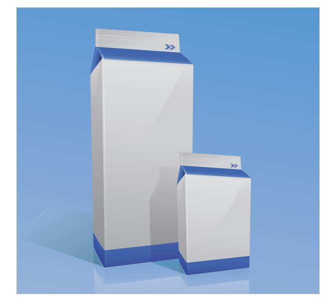
Structure/property | **Function**



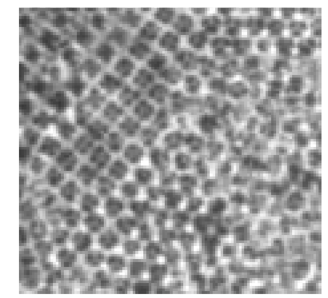


In situ probing of a nanocantilever with a micromanipulator gives valuable insight into microarrays being developed for use in spectrometers for space missions. Courtesy of Ghodssi *et al*, University Of Maryland, USA.



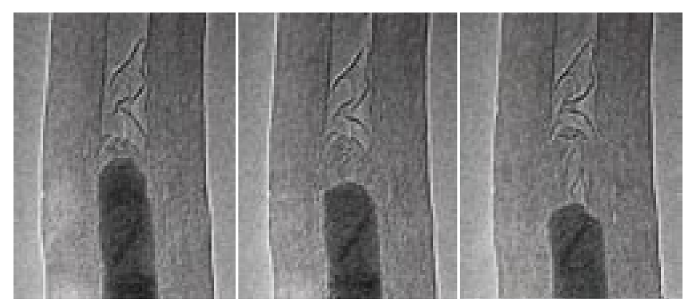


Correlating observations of deformation and failure with mechanical properties by carrying out *in situ* tensile tests, to better understand the behavior of matter, such as this multi-component complex packaging material.

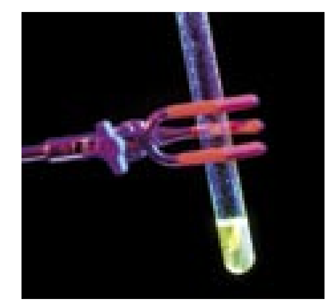


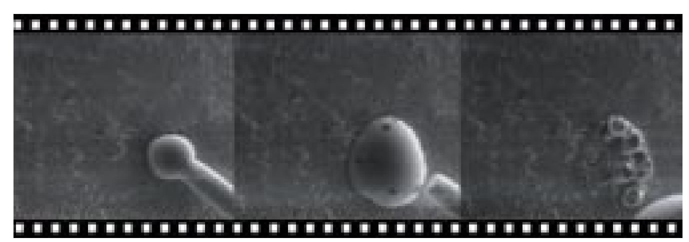
The chemistry of colloidal systems strongly influences their physical behavior. Courtesy of A. Bogner, MATEIS, INSA-Lyon, France.

Structure/property | **Function**



Materials confined within nanotubes potentially provide an *in situ* atomic scale chemical reaction chamber in the TEM - a kind of nano test tube. Courtesy of Julio A. Rodriguez-Manzo, Florian Banhart and Mauricio Terrones, IPICyT, Mexico.





In situ observation of chemical reactions enables a close-up view of processes at surfaces and interfaces, important in the fields of atmospheric chemistry and corrosion science, for example.

Exploring & discovering together

Our continued commitment, dedication and support includes a range of activities such as:

FEI for Owners
Browse online for a wide range of upgrades and accessories.

Scientific collaborations
Ongoing links between FEI Company and research in academia and industry around the globe.

FEI Academy
Training courses to help you get the most from your microscope.

UserClub meetings
Bringing regional and worldwide scientific communities together for discussion, networking and innovation.

FEI Connect
Our thriving, members-only online community for owners and users.

Collaboratory
Adopting the philosophy of providing '...technology, tools and infrastructure that allow scientists to work with remote facilities and each other as if they were co-located'.

FEI received awards

With a rich history of electron microscopy innovation, product design and cutting edge nanotechnology solutions, FEI Company has been the honored recipient of numerous awards and recognitions from industry organizations and publications worldwide.

Titan™ 80-300 S/TEM
- iF Design Award
- State Technology Magazine, Top Products of 2005
- Micro Magazine, Greatest Hits of 2005
- Innovative Product of the Year Award, Oregon Tech Awards 2005
- R&D 100 Award 2006
- IBO's 2006 Silver Design Award
- Award for Technical Excellence, Nano Tech Japan 2008

Tecnai TEM
- Good Design Award (G-Mark), Japanese Industrial Design Promotion Organization (JIDPO)

Phenom™ microscope
- Red Dot product design awards 2007
- Recognition of Excellence in Innovation

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