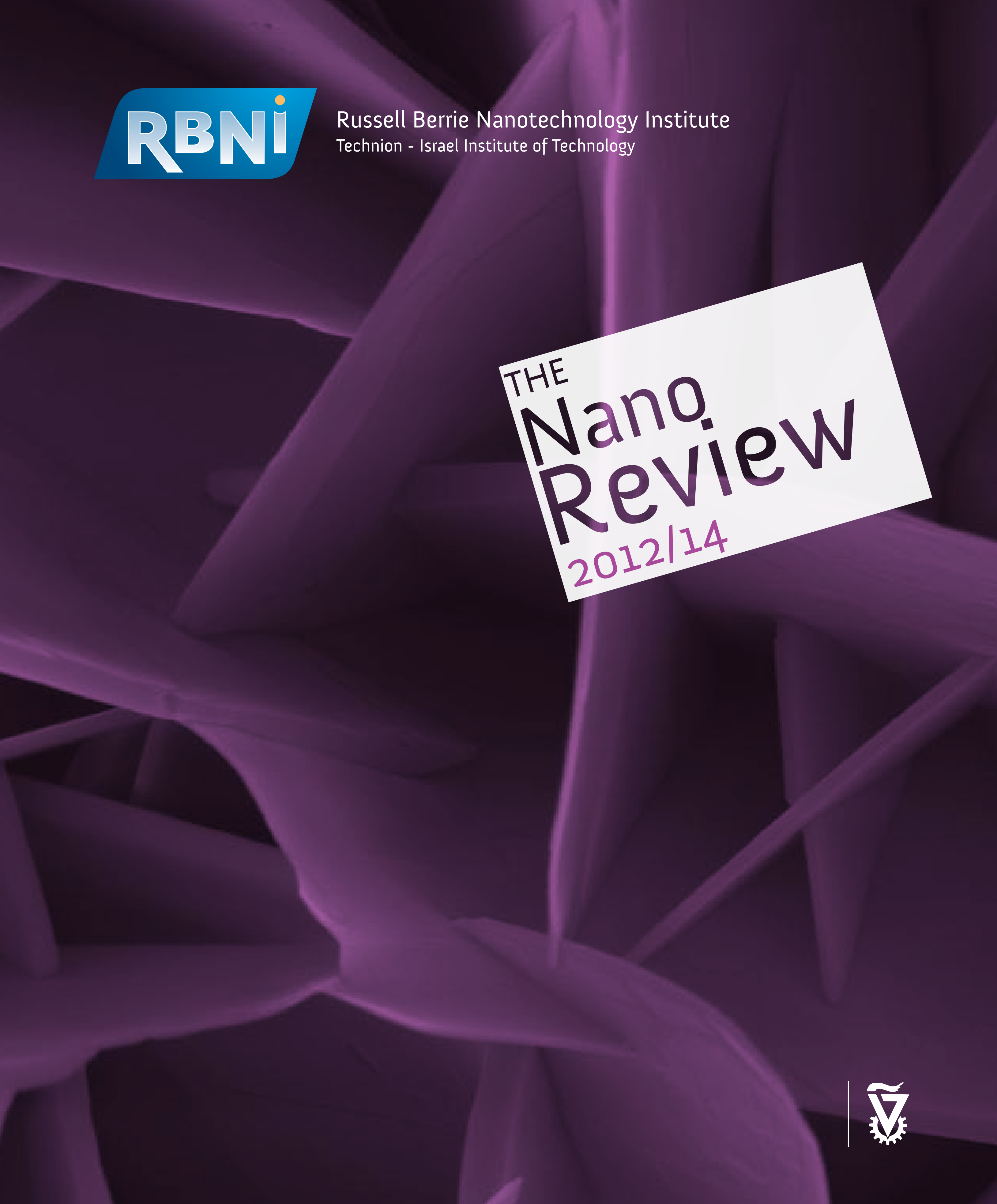
RBNI

Russell Berrie Nanotechnology Institute
Technion - Israel Institute of Technology

THE Nano Review

2012/14



The RBNI vision of transformation that is happening at Technion City, in Israel and across the globe is shared by the philanthropic Russell Berrie Foundation, the Government of Israel through the Forum for National R&D Infrastructure (TELEM) and the Technion - Israel's first institute of technology.

Making real the dream:

Russell Berrie Foundation
Government of Israel
Technion - Israel Institute of Technology

GUARDIAN
Marguerite Barazani Greenberg
Berkowitz Estate
Russell Berrie Foundation
Estate of Lee Goodstein
Sanford Kaplan Trust
Legacy Heritage Fund Limited
Lorry I. Lokey
Rechler Foundation
Ben and Esther Rosenbloom Foundation
Eric F. Ross
Safra Foundation
Norman and Barbara Seiden
Wolfson Family Charitable Trust
Shalom Zielony
Yehuda and Zohar Zisapel

VISIONARY
Fred Adler
Beracha Foundation
Mark Gelfand
Benno Gitter
Estate of Lore Lennon
Alexandre Mallat
Edna and Jonathan Sohnis

MENTOR
Matilda and Gabriel Barnett
Marshall and Marilyn Butler
Alan and Tatyana Forman
Sidney Slauson
Joseph and Bernice Tanenbaum

BENEFACTOR
Norman and Vivian Belmonte
Isabelle and Scott Black
Estate of Raya Cowan
Aaron Etra
Dean R. Feldman
Rod and Sharon Feldman
Gilbert Glass
Joseph Gurwin
Melissa and Jon Hirschtick
Prof. Robert S. and Ellen L. Kaplan
Sonia Mazer
Lena and Vladimir Savikovsky
Rhoda Sohnis
Ing. Sandor and Mariane Szego
Monte Toole
Carol and Robert Weissman

BUILDER
Estate of Dr. Lillian Chutick
Edward Epstein
The Rosalinde and Arthur Gilbert Foundation
Shirley and Marshall Mazer Family
Sandy and Herb Pollack
Queensboro Hill Jewish Centre
Judith and Herman Swartz
Wagner-Braunsberg Family
Wunsch Foundation

FOUNDER
Benjamin Bernstein
Beth and Richard Fentin
Nehemias Gorin Foundation
Herman Gross
Gilda Guttman
Jack Halpern
Judith and Stanley Kolodkin
Howard Salwen and Sheryl Marshall
Neil and Sheryl Sarnak
Lawrence and Cindy Sipkin

PATRON
Benenson Foundation
Dibner Fund
Arthur Eilen
Leo and Julia Forchheimer Foundation
Davi-Linda and David Friedman
Friends of Technion Fund at Combined Jewish Philanthropies
Paula and James Gould
Claire and Sidney Handler
Jewish Communal Fund
Margaret and Marvin Menzin
Gloria and Sonny Monosson
Edith and Sidney Posel
Melvin Rubenstein
Julia and Joshua Ruch
Harold and Anna S. Ullian Charitable Foundation
Peter Wunsch

SPONSOR
Carolyn and Mark Ain
AVR Foundation
Franklin and Barbara Axel
Sally Bendahan
Evelyn Bishop
Eric P. Bloom and Family
Roberta and Irwin Chafetz
Lotte Fields Phil. Fund
Russell Frank
Daniel Goldberg
Susan J. Goldberg
Barbara, Robert and Samuel Goldfarb
Charlotte and Jules Joskow
Walter Kann
Earle and Judy Kazis Foundation Fund
Eugene M. Lang Foundation
Nancy and Sid Lejfer
Deborah and Stuart Levey
Barrie and Ilya Mirman
Esther Mishkin
Herbert and Celia Mittleman
Nelco Foundation
Ephraim and Babette Solomon Radner
Daniel and Brooke Roth
Kenneth and Randee Rubenstein
Donald Salomon
Mildred Samuels
Diane and Mark Seiden
Benjamin Shulkin Charitable Trust
William Sloane Jelin Foundation
SolidWorks Corporation
Alan and Terri Spoon Foundation
Charles D. Wellner
Lenny Zaremba

Pictured: High-resolution SEM micrograph of a Nb-doped $SrTiO_3$ thin (130 nm) film grown by PLD on a $SrTiO_3$ (001) single crystal substrate.

There's Plenty of Room at the Bottom

NanoReview 2013

In 1959, physicist Richard Feynman articulated the future of scientific discovery with a landmark lecture in which he suggested the potential of direct manipulation of individual atoms. Many consider the talk: *"There's plenty of Room at the Bottom"* to have marked the conceptual beginnings of the field of nanotechnology that would emerge decades later.

One nanometer (nm) is one billionth of a meter. This comma, for instance, spans about a million nanometers.

THE Nano Review 2012/14

Nano101

"There is no doubt that the success of the next 100 years of science and technology will be determined by our progress in discovering and applying insights from the nano dimension."
- Prof. Peretz Lavie, *Technion President*

Prof. Peretz Lavie, Technion President

"At RBNI, scientists are determined to ensure that Nanotechnology be understood and applied to make our world a better place."

It gives me great pleasure to introduce the 2013 issue of the Nano Review. The Russell Berrie Nanotechnology Institute (RBNI) is a jewel in the crown of Technion success and a powerful structure generating progress, academic excellence and new discoveries across Technion, Israel and the closely paired worlds of academia and global industry.

As we complete 100 years since the laying of the Technion's first cornerstone, we have cause to give thanks to a century of cornerstones that made significant impact on the evolution of science and technology in Israel and the world. Among these, was the critical and timely foundation of RBNI in January 2005 as a joint endeavour of the Russell Berrie Foundation, the government of Israel and the Technion – Israel Institute of Technology. Today, RBNI is one of the largest academic programs in Israel and is among the largest nanotechnology centers in Europe and the US. There is no doubt that the success of the next 100 years of science and technology will be determined by our progress in discovering and applying insights from the nano dimension.

Indeed, the exemplary educational paradigm created by RBNI in showing a new way to generate multidisciplinary science and education, had an impact on the formulation of the Technion Cornell Institute for Innovation, which is

Making History
A special commemorative stamp honoring 100 Years to the laying of the Technion cornerstone in Haifa, was released by Israel's National Post on January 31st, 2012. The stamp design incorporates the past, present and future not only of the Technion, but also of the State of Israel, and illustrates the country's contribution as a science and technology pioneer. Most prominently, the stamp shows the Technion and RBNI's work in nano science and technology.

presently being established in New York City, and which is formed on the basis of wide, multidisciplinary hubs.

The advantage of structures such as RBNI is that they open the doors to a vast interplay of cooperation between disciplines, faculties, departments, universities and countries. As the traditional boundaries between fields of science, technology and industry break down, the support of such activity is vital to maintaining the pioneering role in unexpected discoveries, where new synergies reveal new possibilities leading to whole new worlds being born.

As you will see in this review, there are four areas where the impact of RBNI on Technion is emerging in a way that is clearly of benefit to all humanity. The first is in the field of nanomedicine. In cooperation with the Lorry I. Lokey Center for Life Science and Engineering, the nurturing and facilitation of multidisciplinary research between physicists, chemists, medics, engineers and biologists is producing a range of new discoveries that will vastly improve our understanding of disease and our ability to come up with remedies – from diabetes, to brain science, through to the vast promise of stem cell research and tissue engineering.

The second area is in finding solutions to the energy crisis. Working with the Grand Technion Energy Program (GTEP), RBNI scientists are pioneering new solutions that bring the promise of overcoming the scientific barriers to the efficient production of clean energy. As world oil reserves deplete, the importance and urgency of this work cannot be overstated – and many of the solutions and refinements can only be found through interaction in the nano dimension.

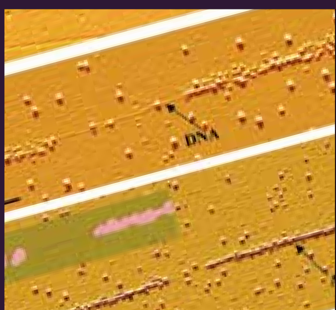
A third area is the new Focal Technological Area, which has recently been approved for funding by the Government of Israel and the Technion, and will take place over the next 5 years. This Focal Technological Area focuses on Nanophotonics for Advanced Light Detection Imaging, Inspection, Smart Sensors, and Energy Conversion, led by Prof. Meir Orenstein from the faculty of Electrical Engineering. Nanophotonics opens new frontiers in sensing for medical and environmental purposes, imaging, computing and communication.

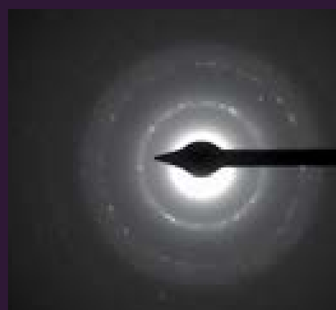
The fourth area is in the interface with industry. At Technion, we are pioneers of new discoveries. But a special Technion quality is that we do not rest until we see our big ideas put to work – applied in a way that makes a real difference to the lives of all. Innovations arising out of RBNI research are rapidly taken on through a dynamic process of technology transfer. They become start-ups. They become products commercialized by industrial partners. They become relevant to us all. Expert technology transfer is especially important in an emerging field such as nanotechnology – in order for entrepreneurs to truly understand the value of what science has made possible – and to become partners in making that scientific discovery of value to the world.

At Technion, our support of RBNI and its excellent researchers and students is unwavering. We look forward to sharing with you the nano future – the uncovery of the nano dimension that is already having such an impact on the quality of our lives.

Shaping the Future.

As Technion celebrated its cornerstone centennial, many of the most powerful landmarks in its present standing as a world leading institute of advanced science and technology were the products of the intensive work of RBNI researchers to enable the nano revolution in Israel. Here are just seven of RBNI's historic nano moments.





I 2003

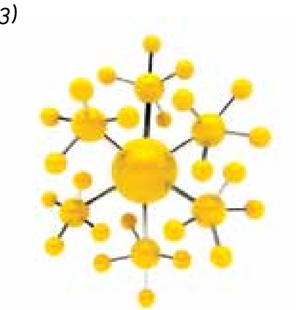
Prof. Uri Sivan, Assis. Prof. Kinneret Keren, Prof. Erez Braun, Prof. Evgeny Buchstab and Rotem S. Berman, an M.Sc. student, created DNA Templated Carbon nanotube Field-Effect Transistor. A critical advance in electronics, carbon nanotubes are now widely recognized as the next step in squeezing an increasing number of transistors onto a chip, vastly increasing computer speed and memory while reducing their energy consumption. (*Science, Nov. 2003*)

II 2004

The promise of nanomaterials in a new generation of wastewater-purification systems resulting from a research team led by Prof. Rafael Semiat.

III 2004

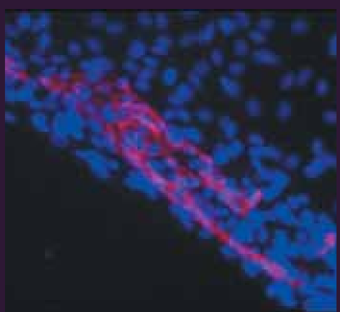
Vibrating carbon nanotubes, or amazingly tiny parachutes made of electrospun nanofibers from the lab of Prof. Eyal Zussman, reveal a multidisciplinary potential. One application is cited as a detection system for airborne chemical toxins and other environmental contaminants.

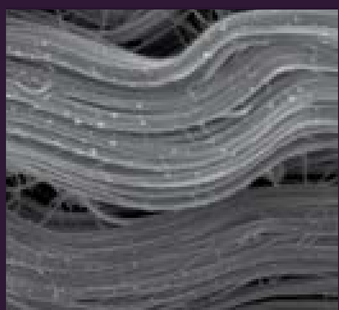


> "Substances behave magically at the Nanoscale because that's where the essential properties of matter are determined."
>
> -Kahn Jennifer, *National Geographic, 2006*

"Just as silicon transistors replaced old vacuum tube technology and enabled the electronic age, carbon nanotube devices could open a new era of electronics."

-Margaret Blohm, GE's
Advanced Technology Leader for Nanotechnology





IV 2006

Prof. Shulamit Levenberg is chosen by the prestigious journal *Scientific American* as one of the 50 leading young scientists, honoring her development of a system for creating tissue from stem cells that the body does not reject.

V 2009

Scientists working with Prof. Uri Sivan, introduce the Nano-Bible, printed on an area the size of a pinhead. It is presented to the Pope as a gift from Mr. Shimon Peres, President of the State of Israel, and now hangs in the Vatican.

VI 2009

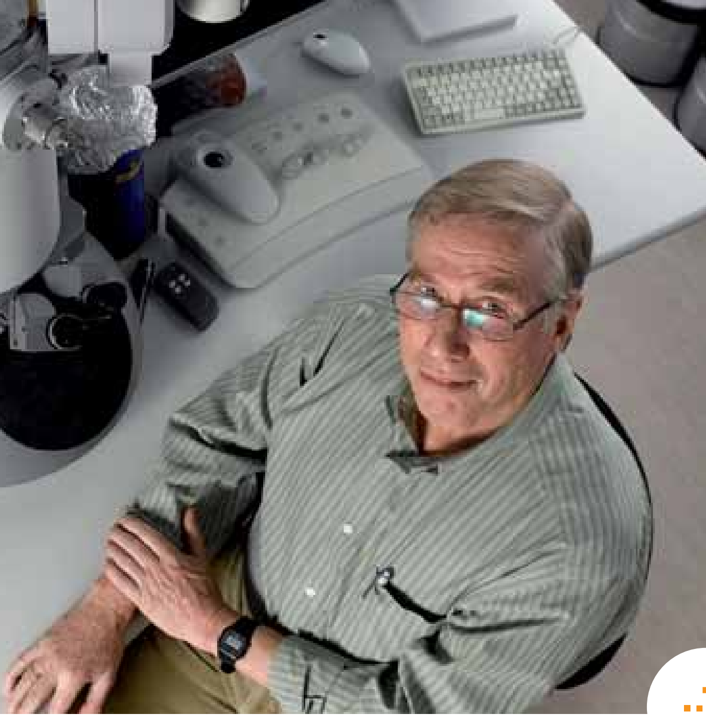
Professor Ishi Talmon and colleagues at Rice University unveil a method for the industrial-scale processing of pure carbon-nanotube fibers that could lead to revolutionary advances in materials science, power distribution and nanoelectronics.

"Nanotechnology is manufacturing with atoms"

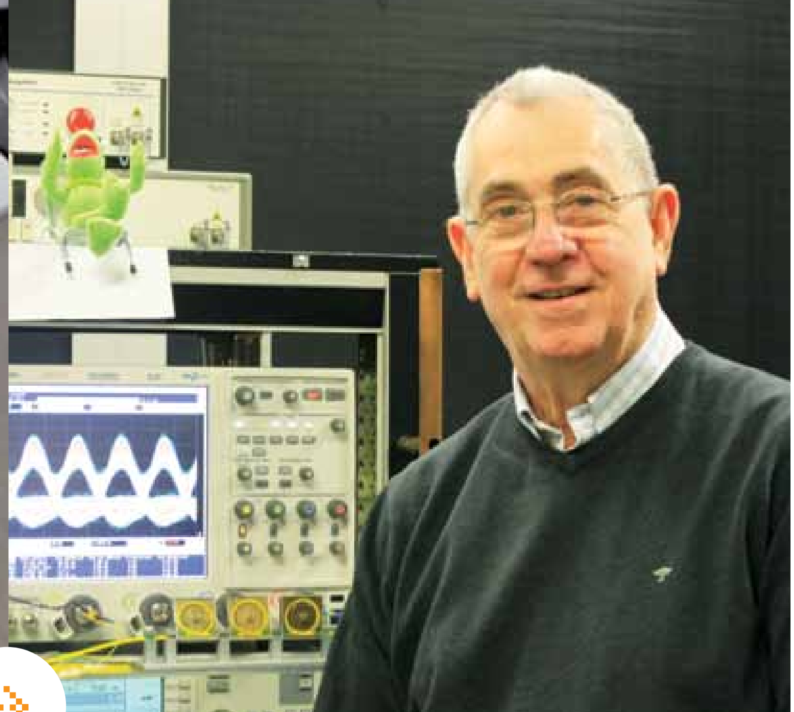
- William Powell (1892 - 1984)

VII 2010

Prof. Hossam Haick introduces the patented CNTnose – a breath test that uses several advanced sensors and innovative software to detect chemical compounds that appear in the breath of people with head, neck and lung cancer.



Prof. Yeshayahu Talmon, RBNI former director



Prof. Gadi Eisenstein, RBNI director starting January 2013

Nanovanguard

"We know that Nano science will change the world... now it's time to think about how."
- Prof. Ishi Talmon, RBNI former Director

We know that nano science will change the world... now it's time to think about how. At RBNI, scientists are determined to ensure that the nanotechnology will be understood and applied to make our world a better place today. It is clear that nanotechnology is the basis for the next industrial revolution. Nanotechnology is everywhere, in our medicines, clothing, cars, windows, computers, displays and cosmetics. Substances behave magically at the nanoscale because that's where the essential properties of matter are determined. It is helping us address global challenges such as climate change, constraints in energy production and shortage of resources, insufficient access to clean water and food safety, as well as widespread diseases, and affordable health care. It is key to potential future markets worth billions of dollars annually yet, the true potential of nanotechnology is still to be discovered.

As RBNI concludes its eighth year of activity, its impact on science and education in Israel and on global Nano research is becoming increasingly apparent.

Over 150 faculty members and 250 graduate students from 14 faculties, conduct state-of-the-art research in nano-electronics, nano-optics, nano-materials, nano-mechanics and the interface between those fields and the life sciences.

RBNI members come from a variety of faculties, including: Electrical Engineering, Materials Science and Engineering, Mechanical Engineering, Chemical Engineering, Biomedical Engineering, Aerospace Engineering, Biotechnology and Food Engineering, Biology, Medicine, Chemistry, Physics, Mathematics, Computer Science, as well as Civil and Environmental Engineering. This vibrant multidisciplinary nano-

PROGRAM PHASES

CAMPUS-WIDE PROGRAM	PHASE I	PHASE II	PHASE III
2002 - 2004	2005 - 2009	2010 - 2014	2014-2018

community is empowered through joint RBNI monthly seminars, Winter Schools and Fall Symposia. Special research funding programs enhance multidisciplinary nano-activities on campus.

In addition, RBNI continues its vigorous recruitment of bright new faculty from research labs around the world and researchers labs upgrade; its extensive investments in infrastructure; and its new educational programs for training the next generation of scientists and engineers.

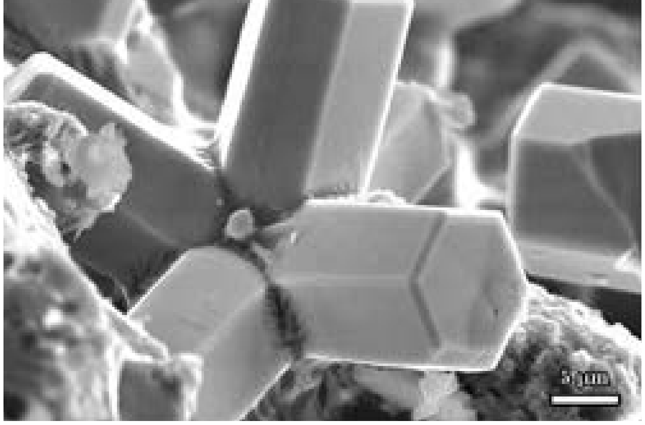
RBNI's channel for promoting innovative research within and outside Technion is the "Nevet" program. Grant applications submitted by two or more researchers are reviewed by a panel of leading Israeli scientists, and winning proposals receive a one-year seed grant. The results obtained during that year and the proven collaboration have a significant impact on the researchers' ability to recruit further funding. Overall, 90 Nevet research projects have been selected for funding between 2005-2012 with matching funds by the partner institution except for internal Technion Nevet grants which are fully funded by RBNI.

Dozens of workshops and meetings have brought together RBNI scientists with colleagues from universities and leading institutes from the US, Europe, Asia, and Australia. These workshops yielded successful collaborations such as the NUS, NTU, Aachen, Karlsruhe and NanoGune nano centers.

RBNI will significantly enhance its international visibility through collaborative programs in the next five years. 188 collaborative programs have been launched to date between RBNI and industry, including Magneton and Kamin programs as well as participation in MAGNET consortia. Over 118 patents have been filed between 2005-2011. Nine additional patents have been licensed during 2011. 53 industrial companies used RBNI infrastructure facilities in 2012 alone. RBNI launched in 2011 a nanotechnology Industry-Technion CTOs forum to facilitate dialogue between Israeli industry and the Technion nano community in order to further strengthen collaboration in research and development.

The conclusion of the eighth year of activities at RBNI shows the dramatic impact the institute has had on Technion and on Israeli academia and industry. RBNI is increasingly consolidating its position not only as a pioneer in nanotechnology, but also as the educational paradigm for multidisciplinary work. Our future depends on the vision and support of our friends and partners across the world, and this edition of the Nano Review is dedicated to them.

Distinguished Prof. Dan Schechtman, 2011 Nobel laureate in Chemistry with the Titan, atomic-resolution transmission electron microscope purchased by RBNI.

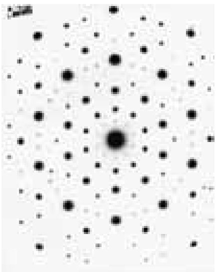


Crystals of $Mg_{23}Zn_{63}Y_{11}$ ternary phase, Mg-Zn eutectics & Mg matrix in Mg-Zn-Y alloy. Acquired using the LEO by Sergei Remennik (Distinguished Prof. Dan Shechtman).

"Without the Electron Microscope we would never have been able to make the discovery."

- Distinguished Prof. Dan Schechtman

Nanovanguard



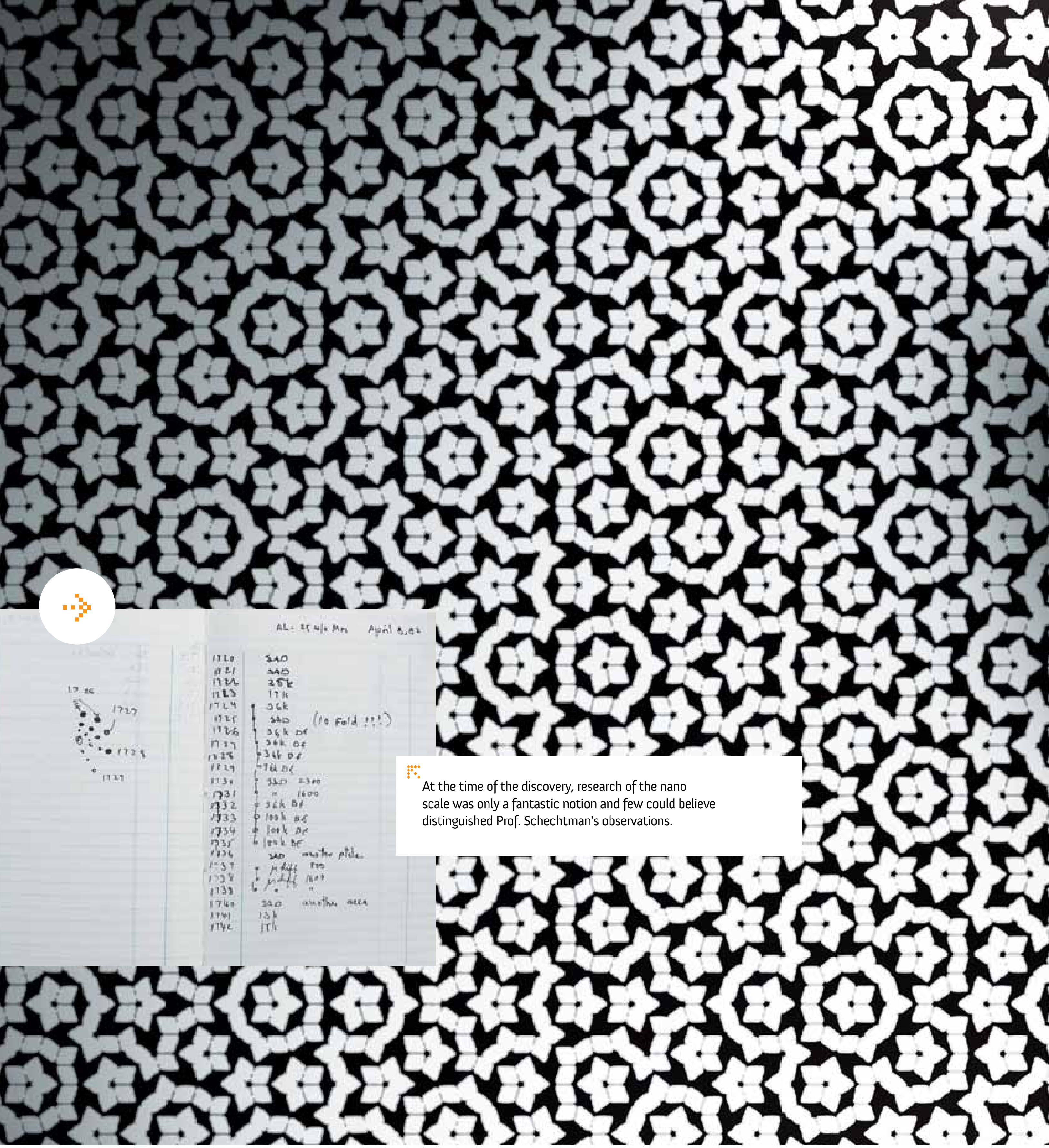
Difraction pattern of a quasicrystal as seen through a transmission electron microscope.

In December 2011 it was announced that distinguished Prof. Dan Shechtman was to receive the Nobel Prize for Chemistry, making him the Technion's third scientist to receive the world's highest honor. The Nobel was awarded to honor distinguished Prof. Shechtman's discovery of a new kind of matter – quasicrystals – a discovery that opened an entire new field of crystallography.

Distinguished Prof. Dan Shechtman discovered quasiperiodic crystals in April 1982, as a visiting scholar at the National Bureau of Standards in Maryland, USA. This form of matter – also known as Shechtmanite – possesses some unique remarkable crystallographic and physical properties, embodying a novel kind of crystalline order.

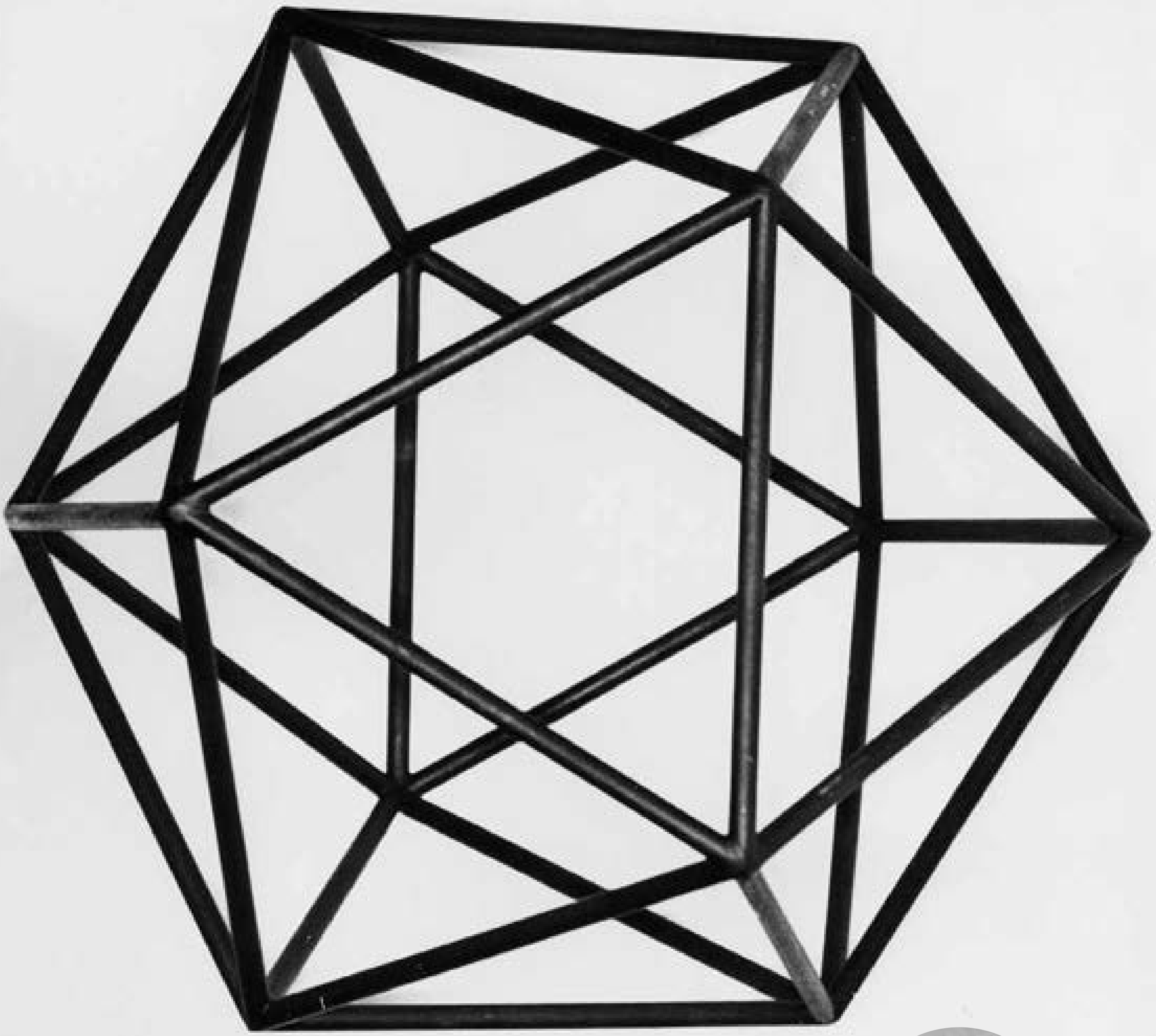
His findings demonstrated a clear diffraction pattern with a five-fold symmetry. The pattern was recorded from an aluminum-manganese (Al-Mn) alloy, which had been rapidly cooled after melting. Today, over 40 scientific books have been dedicated to quasiperiodic crystals, and the International Society of Crystallography has changed its basic definition of a crystal, reducing it to the ability to produce a clear-cut diffraction pattern, and acknowledging that crystallographic order can be either periodic or aperiodic.

Today, distinguished Prof. Shechtman uses the powerful Titan microscope – purchased by RBNI in 2005 and one of just a handful worldwide – to pursue his research. "This microscope is considered the most advanced of its kind," says distinguished Prof. Shechtman, "It is a very powerful, high resolution, microscope... much more so than the one we used to discover quasicrystals."

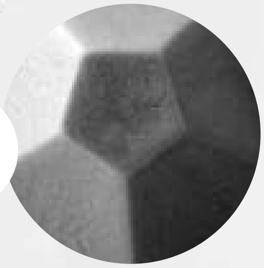


At the time of the discovery, research of the nano scale was only a fantastic notion and few could believe distinguished Prof. Schechtman's observations.

A model of Prof. Schechtman's five fold symmetry.



This is a quasicrystal!



Research Highlights

Nanocrystals for Solar Power

An RBNI researchers team led by Prof. Nir Tessler at the Sara and Moshe Zisapel Nano-Electronics Center, successfully polarized a nanocrystal by changing the composition of the molecules surrounding it.

The discovery will likely have far-reaching consequences for the improvement of the efficiency of solar cells. These are third generation photovoltaic cells that are being intensively developed around the world due to their relatively low cost (and therefore, their suitability for mass production).

Needle-free blood tests

An RBNI team has demonstrated a non-invasive technique for imaging blood cells in vivo that could remove the need to extract blood from many patients.

Powered by the Andor Newton Electron Multiplying EMCCD camera, their high-resolution Spectrally Encoded Flow Cytometry (SEFC) probe offers primary care physicians the ability to detect a wide range of common medical disorders, without extracting blood. The method, developed by the Biomedical Optics Laboratory, headed by Dr. Dvir Yelin, would allow immediate medical response, as well as large-scale screening for common blood disorders.

Water the World

Sustainable agriculture is conditional upon irrigation with good quality water, yet farmers are rapidly losing their share of this precious resource. Irrigating with recycled wastewater fills this loss and presents an environmentally acceptable way for wastewater disposal.

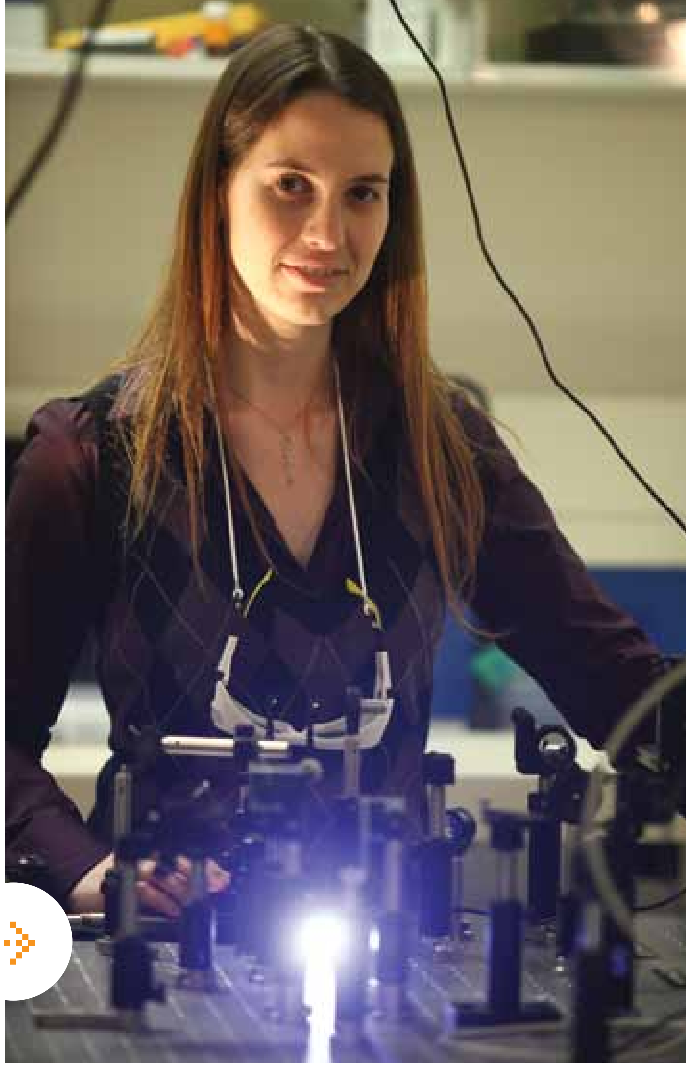
RBNI Prof. Raphael Semiat and his team recently installed an advanced membrane system for the ultimate effluent purification, yielding water for unrestricted use. Located at the Carmel Coast Regional Council's secondary wastewater treatment Nir Etzion site, the system is part of the second stage of a Palestinian-Jordanian-Israeli Project supported by the Peres Center for Peace and the USAID-MERC program.

Spinoptics

The spin Hall effect – the impact of the intrinsic spin on the particle trajectory, which produces transverse deflection of the particle – is a central tenet in the field of spintronics regarding particles of electrons. Now, its optical equivalent has been observed by RBNI scientists. The Magnus effect is seen in a wide range of systems. For example, it describes the sideways force applied to a spinning ball as it travels through the air explains Prof. Erez Hasman, head of the Micro- and Nanooptics Laboratory.

Light waves, comprising mass-less particles called photons, also demonstrate spin. Light's spin is determined by its polarization: whether the wave vibration rotates in one direction or the opposite as it travels. Prof. Hasman, together with his Ph.D. student Avi Niv, Dr. Vladimir Kleiner – a senior scientist in the lab, and Ukrainian visiting scientist, Dr. Konstantin Bliokh, were the first to observe the effect of spin on the trajectories of polarized light beams.

“The Technion is one of the most celebrated technical universities in the world.”
- Dr. Santiago Calatrava



Gili Bisker, Ph.D. Nanoscience & Nanotechnology Graduate Program student.

Pure Gold

RBNI graduate program student Gili Bisker has been named a “For Women in Science” International Fellow, a designation for young scientists. As an Israeli finalist in the 2012 worldwide L’Oréal-UNESCO “For Women in Science” awards, she will receive a cash prize to be used towards post-doctorate work abroad. With two others, she will represent Israel in the worldwide contest, where the winners in each of five world regions earn prizes of up to $100,000. Bisker is developing new treatments for cancer based on controlled release of drugs derived from Nano-particles of gold, and administered using short laser pulses.

New method for treating Diabetes

RBNI researchers in tissue engineering have constructed a polymeric scaffold array with pancreatic islets surrounded by a vascular network. This heralds the potential for the fabrication of transplantable “islets.” “We have shown that the three-dimensional environment and the engineered blood vessels support the islets. This support is important for the survival of the islets and for their insulin secretion activity,” says Prof. Shulamit Levenberg of the Department of Biomedical Engineering. “We have shown that these laboratory-made polymeric scaffolds can be transplanted subcutaneously, and can heal a diabetic mouse.”

Research Highlights

Resolution x10

RBNI researchers have developed a computational method for improving the resolution of microscopes and imaging systems. The method is hailed as being a "breakthrough with the potential to change the world of microscopy, imaging systems, and other optical measurement systems."

"When you look through an optical microscope at an object with features (optical information) smaller than one half the wavelength of light – you necessarily see a blurred image," explains Distinguished Prof. Mordechai (Moti) Segev of the Technion's Faculty of Physics.

Experiments demonstrated reconstructions of objects with optical features 100 nanometers in size using radiation with a wavelength of 530 nanometers. In comparison, without using the new method, the resolution of this microscope is limited to features bigger than 300 nanometers.

Nano powders and pseudo-elasticity

Prof. Eugene Rabkin and Assis. Prof. Dan Mordechai from the department of Materials Science & Engineering and RBNI members have discovered a new mechanism for adhesive contact formation between crystalline nanoparticles, and have thus shed light on a long-standing mystery surrounding the adhesion between nanocrystals.

Researchers used advanced simulation tools that run on high-performance parallel computer located on campus. Coining the term: "pseudo-elasticity," they revealed a mechanism that enables nanocrystals to retain their original shape, despite the forces acting upon them, which are large enough to overcome their own strength limit. This mechanism may have great importance in many additional fields in contact mechanics for each pair of bodies that gets within a few nanometers of each other.

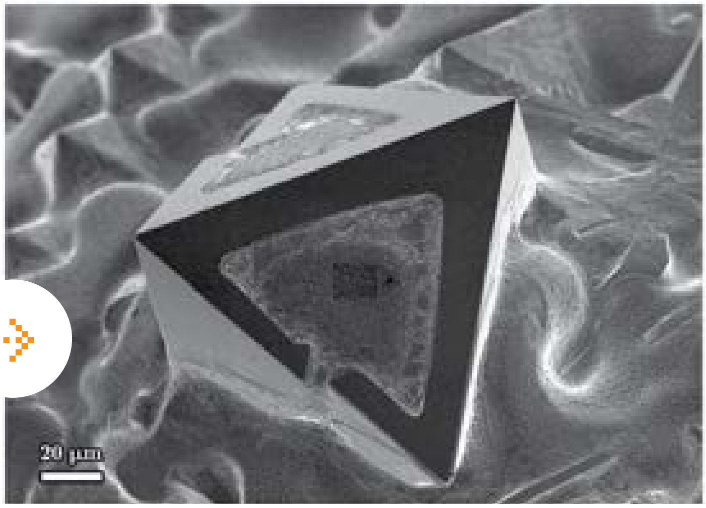
Decoding human speech

RBNI researchers are part of an international team that could bring the power of speech to sufferers of paralysis, through a direct brain-computer interface. Prof. Shy Shoham and Dr. Ariel Tankus of the Technion Department of Biomedical Engineering worked with researchers from UCLA to decipher the way neurons in different areas of the human brain encode different speech segments (vowels) during their articulation.

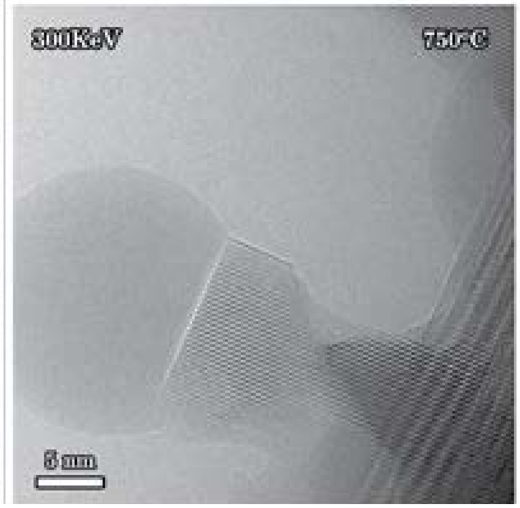
The discovery will indirectly enable scientists to decode the content of the subjects' speech based on brain activity alone. One of the possible applications of speech decoding from brain activity is the creation of a brain-computer interface that can restore speech faculties in paralyzed individuals who have lost them.

Into Tissue

Looking to the future, where the world-wide use of stem cells for healing will require mass production, Prof. Dror Seliktar of the department of Biomedical Engineering and an RBNI member is working on a new material for the mass production of stem cells to make their commercial use viable on an industrial scale. "In the biotechnology industries, there is an inherent need for expanding populations of stem cells for therapeutic purposes," says Prof. Seliktar of the



An Al86Mn9,5Ce4,5 Octahedron crystal growing from a dendritic like structure observed in a crystal grain. Acquired using the LEO by Lilia Glazman (Distinguished Prof. Dan Schechtman).



HRTEM image of a liquid Al drop on a sapphire substrate at 750°. Acquired using the Titan by Dr. Yaron Kauffmann and Miri Drozdov (Prof. Wayne D. Kaplan).

Department of Biomedical Engineering, who has published over 50 papers in the field of biomaterials and regenerative medicine, and won over 14 awards.

A patented customized gel developed by the team provides the substrate needed by stem cells to grow and multiply in these industrial bioreactors. “Using our material technology, we have the ability to adapt stem cell cultivation into a three-dimensional suspension reactor system,” says Prof. Seliktar, Head of the Norman Seiden Nanoscience and Nanotechnology graduate program.

Gibbs Theory Resolved

RBNI researchers have resolved the 133-year-old Gibb’s theory of 1870's, by revealing the nature of Nanometer-scale layers between materials.

Under the supervision of Prof. Wayne Kaplan, Dr. Mor Baram proved through a series of experiments, that a layer exists at the interface between metals and ceramic materials, and apparently also at the interface between metals and semiconductors. “This phenomenon enables us to ice-skate, reduces the mechanical properties of ceramic materials at high temperatures, but seemingly contributes to the stability of innovative micro-electronic devices,” says Prof. Kaplan.

The discovery will enable scientists to improve the resilience of the bond between ceramic materials and metals. Examples include the joining of missile domes to missiles, the connection between metal conducting wires and chips in computers, and the protective ceramic coating on blades of jet engines.

Focal Technological Area (FTA)

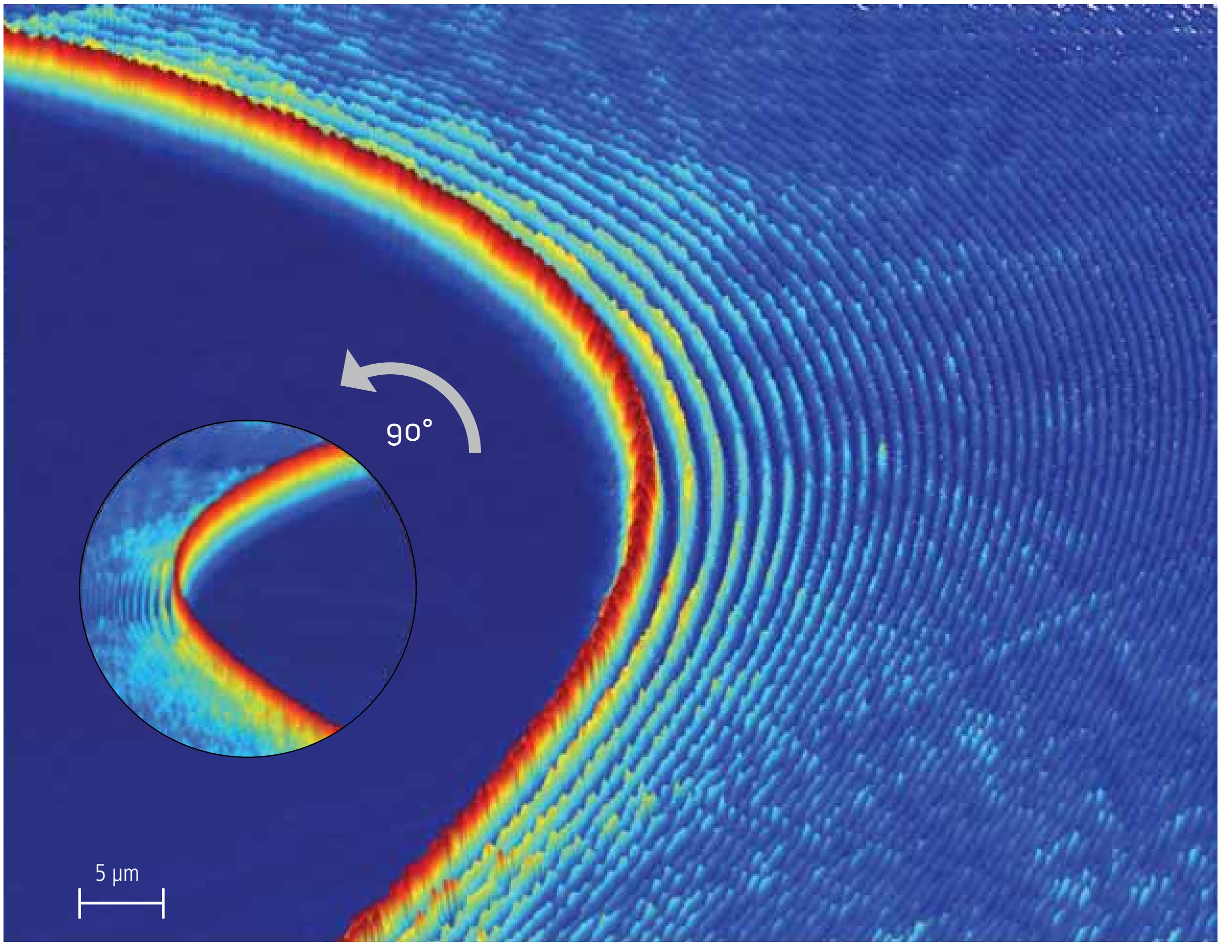
Nanophotonics for Detection and Sensing

This recently innaugurated RBNI umbrella research program, is sponsored by the government of Israel and by Technion. This major, campus-wide, applied science endeavor will critically impact technology and science in the field of novel photonic devices, and more generally, Israeli industry, defense, health care and society as a whole. The program, directed by Prof. Meir Orenstein (Electrical Engineering, Technion), is comprised of 11 Technion research groups and three guest teams (Weizmann Institute, Hebrew University and Tel-Aviv University).

Photonics involves seeing, probing, inspecting and communicating with photons – elementary light particles. The Technion's nanophotonics team, comprised of an outstanding interdisciplinary team from the Faculties of Physics, Electrical Engineering, Mechanical Engineering, and Materials Science & Engineering, is taking leadership in developing nanophotonic devices with recognized scientific impact.

The Technion's efforts to undertake photonics research at the nano-level include privileged ties with industry. Considerable Israeli high-tech industrial activity makes use of photonics. This activity spans the range of applications from advanced light detection systems and imaging devices, to distributed and environmental sensors, defense and security systems, medical diagnostics, automotive applications, ultra-high-resolution industrial inspection, solar cells and optical communications.

The potential for the miniaturization of light detection to the nano-scale is tremendous and multifaceted.



Self-Accelerating Beams (Distinguished Prof. Moti Segev lab).

The nano-scale offers a microscopic “footprint” necessary for a multitude of applications (as with medical intra-body devices); permits for increased sensitivity by generating less interference (as in the detection of isolated molecules); has great promise for health-care, environmental and security applications; promises attractive cost absorption and power optimization (as with ultra-thin-layer solar cells); amplifies resolution (beyond the limits of existing microscopy); boosts speed and enhances functionality (as with detectors). To achieve such miniaturized light detection devices, it is necessary to embed them in nanophotonic structures that enhance the efficiency of the thin absorbing layers, modify their functionality and mitigate the incompatibility between the large dimensions of the micrometric light photons and those of the nanodetector.

Among the products and solutions expected to emerge or to benefit from this research are efficient organic and hybrid thin-layer solar cells; efficient solar-electrochemical cells; nanodetectors for low light level imagers (electronic cameras) in the ultraviolet, visible, infra-red regimes; imagers with smart pixel (multispectral, polarization); nanophotonic advanced sensors (smart-dust – ultra-tiny sensors that can be dispersed); enhanced medical probes; extreme resolution inspection systems for microelectronics and biomedical applications; high-resolution microscopy and Optical Coherence Tomography (OCT); nanophotonic circuits including flexible circuits for sensing; and integrated communications transceivers.

Nanomed

Often, a first proof of worth of new understandings in the nano-dimension is the emergence of innovative medical solutions. The power of nano to impact pharmacology, surgery, diagnostics and medical treatments is such that RBNI is part of a concentrated initiative to empower this life-saving research.

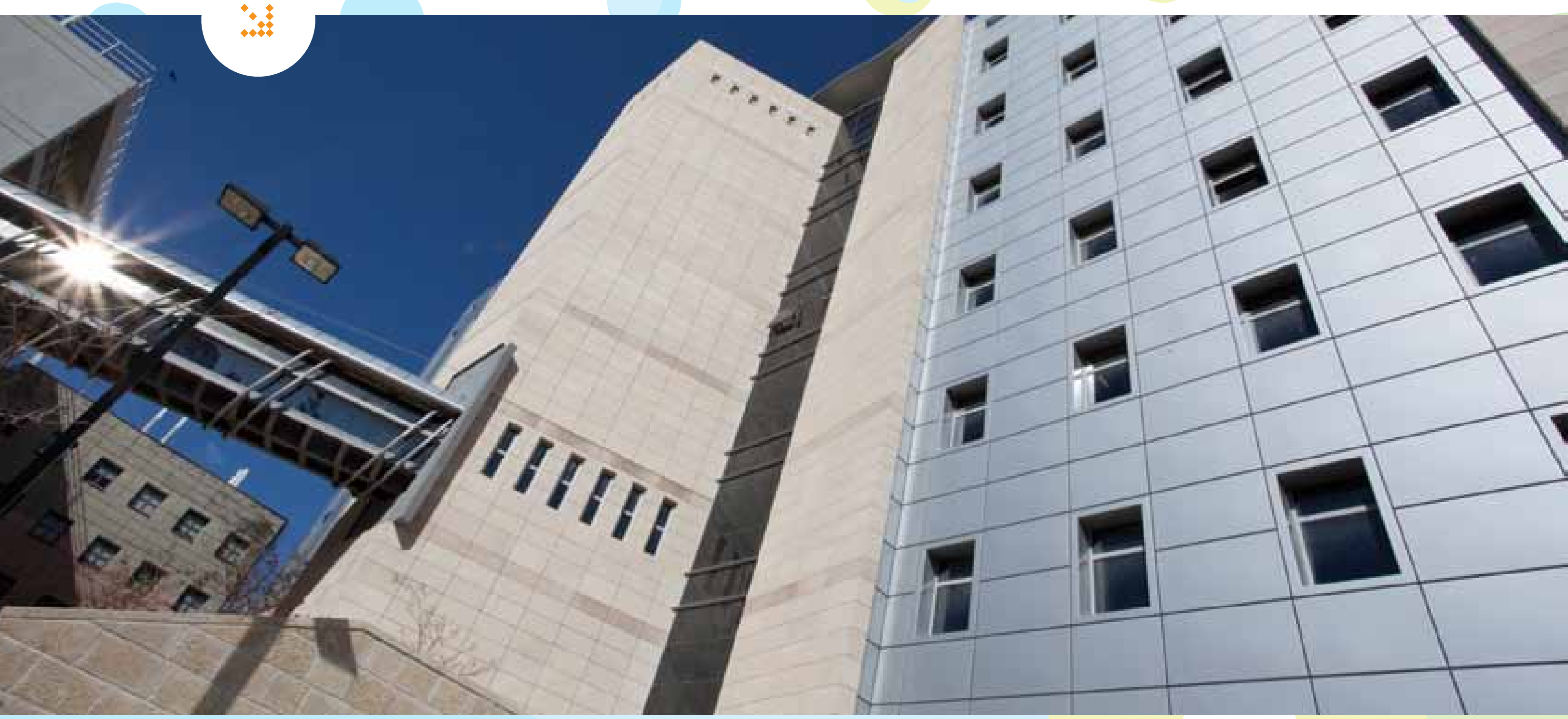
Today at Technion, researchers from different disciplines cooperate to achieve the shared goal of saving lives. This is history in the making – as synergy between two world-class multidisciplinary fields at Technion – Nanotechnology and Life Sciences – is initiating a life-saving center of expert science in the form of NanoMedicine. Bringing together the Technion's experts with new faculty members recruited from around the world, the center focuses on biomedical imaging, novel disease biomarkers, targeted drug delivery, regenerative medicine, nano scale sensors and nano tools for medicine.

The NanoMed Center is a natural scientific evolution of the two largest academic research programs on campus: the Russell Berrie Nanotechnology Institute (RBNI) and the Lorry I. Lokey Multidisciplinary Center for Life Sciences and Engineering.

Professors Yuval Shoham and Ishi Talmon, former directors of the Lorry I. Lokey Multidisciplinary Center for Life Sciences and Engineering (LS&E) and RBNI collaborated on the Nanomed program development which was originally conceived by Nobel laureate distinguished Prof. Aaron Ciechanover, first director of LS&E and Prof. Uri Sivan, the first director of RBNI.

MSc and PhD students working in the Nanomed program are enrolled in the RBNI graduate program. LS&E and RBNI fund jointly the following activities:

- Infrastructure equipment.
- Start-up funds for faculty laboratories and laboratory upgrades.
- User fees subsidy for infrastructure centers.



Nanoenergy

I. Alternative fuels
- Non-carbon fuels
- Biomass-based fuels
- Hydrogen technology

II. Energy storage and conversion
- Energy storage
- Fuel cell technologies

III. Renewable energy
- Photovoltaics
- Wind power
- Solar thermal energy

IV. Energy conservation
- Energy saving measures
- Efficient buildings

Nano and world power

Nano is impacting energy research across a wide spectrum, from the development of more effective solar energy systems, to engineering particles to revolutionize the power grids of the future.

One example is Prof. Efrat Lifshitz, who discovered that nano-sized materials consisting of nanocrystal quantum dots can absorb sunlight not only in the visible range, as materials currently used in solar panels do, but also in the infrared and UV ranges. This makes them ideal in photovoltaic cells used to turn sunlight into electricity, promising more efficient solar power.

At the Faculty of Electrical Engineering in another dynamic laboratory, Prof. Nir Tessler of the Electrical Engineering faculty and an RBNI member, leads the organic photovoltaic materials group.

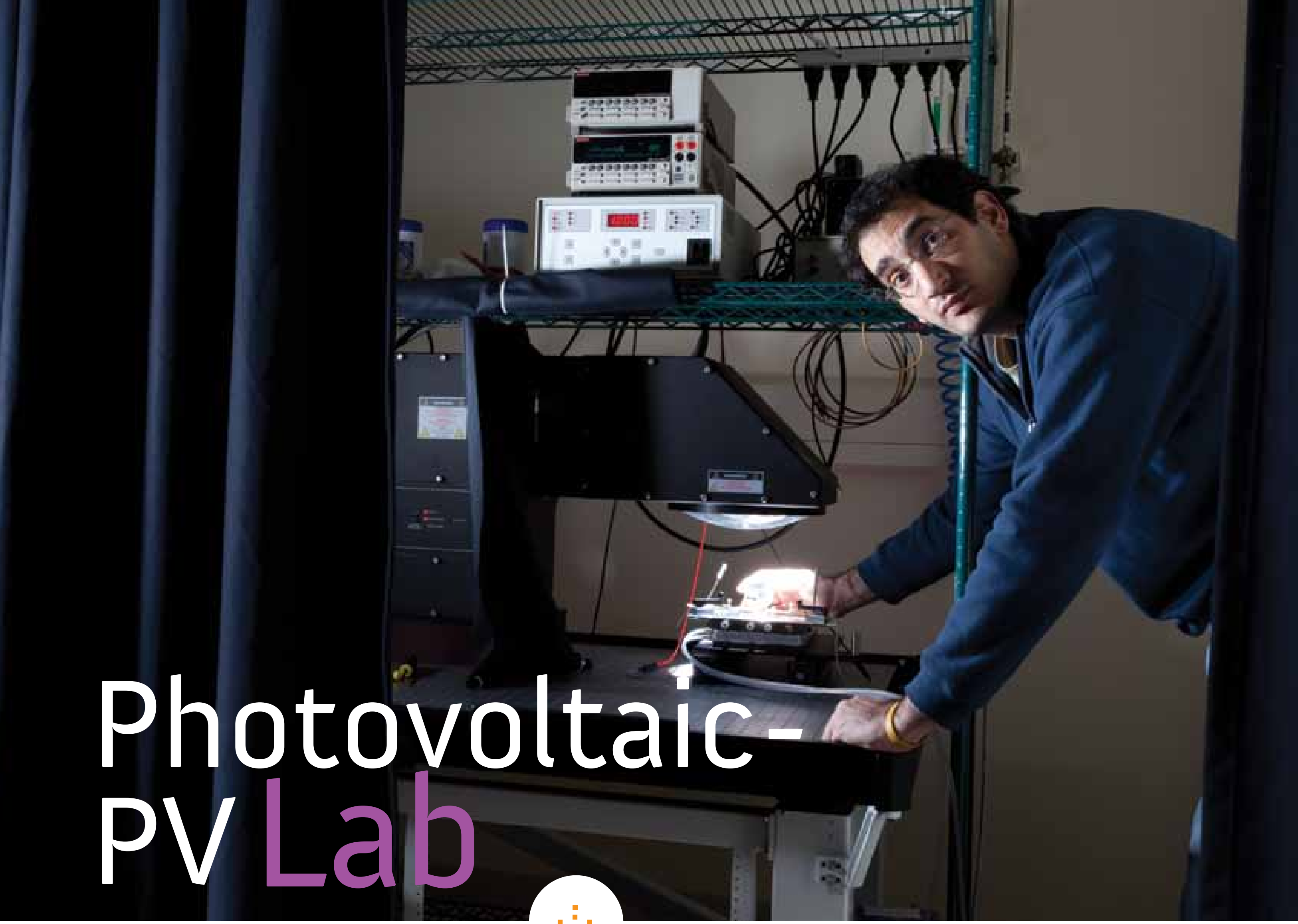
"We're trying to use nano-scale understanding and capabilities to produce microscale devices, and through the nano we simply improve their properties and performance," explains Tessler.

THE GTEP POWER AGENDA

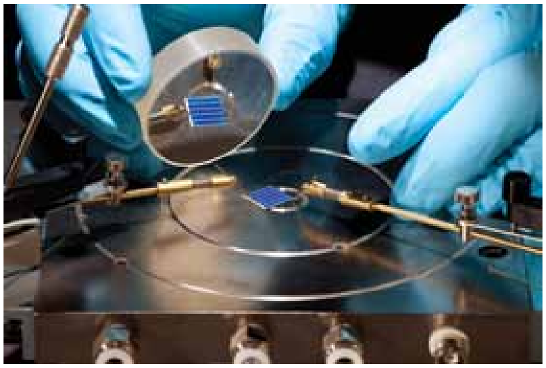
Nano scientists are making breakthroughs with new energy sources in mind; they turn frequently to Nano in order to engineer the substances and materials they need to repower our world. As a result, cooperation between the Technion's Russell Berrie Nanotechnology Institute (RBNI) and the Nancy and Stephen Grand Technion Energy Program (GTEP) is dynamically creating new alliances of excellence. As so many of the barriers to the generation of alternative energy sources depend on solving problems at the nanoscale, the development of nano-knowhow, and infrastructure is proving vital in the creation of the energy technologies of tomorrow.

RBNI joined the GTEP to set up new research facilities for fabrication and testing of photovoltaic devices. Equipment jointly purchased by GTEP and RBNI serves the entire Technion community as well as researchers from Israeli academia and industry, in addition to equipment purchased in cooperation with other centers.

Photovoltaic-PV Lab



Dr. Guy Ankonina, Lab Manager at the Photovoltaic Lab.



"We see it (nanotechnology) as having virtually unlimited potential to transform the way we produce, deliver, and use energy..."

- U.S. Energy Secretary Spencer Abraham

TAMNUN inauguration. *From left to right:* Prof. Oded Shmueli, Executive Vice President for research, Prof. Ishi Talmon, former RBNI Director and Dr. Avital Stein, former Executive Vice President and Director General.

PV Lab

The facility is located in the Zisapel building. It comprises a characterization lab and a device fabrication facility placed in the Clean Room complex. The lab personnel offer technical services and assistance in the design, fabrication and characterization of organic, inorganic and hybrid PV devices.

"Here, there is the freedom to explore what you think is right, in order to gain knowledge," says Lab Manager Dr. Guy Ankonina. "Scientists can explore all frontiers of PV... what was not known, becomes known."

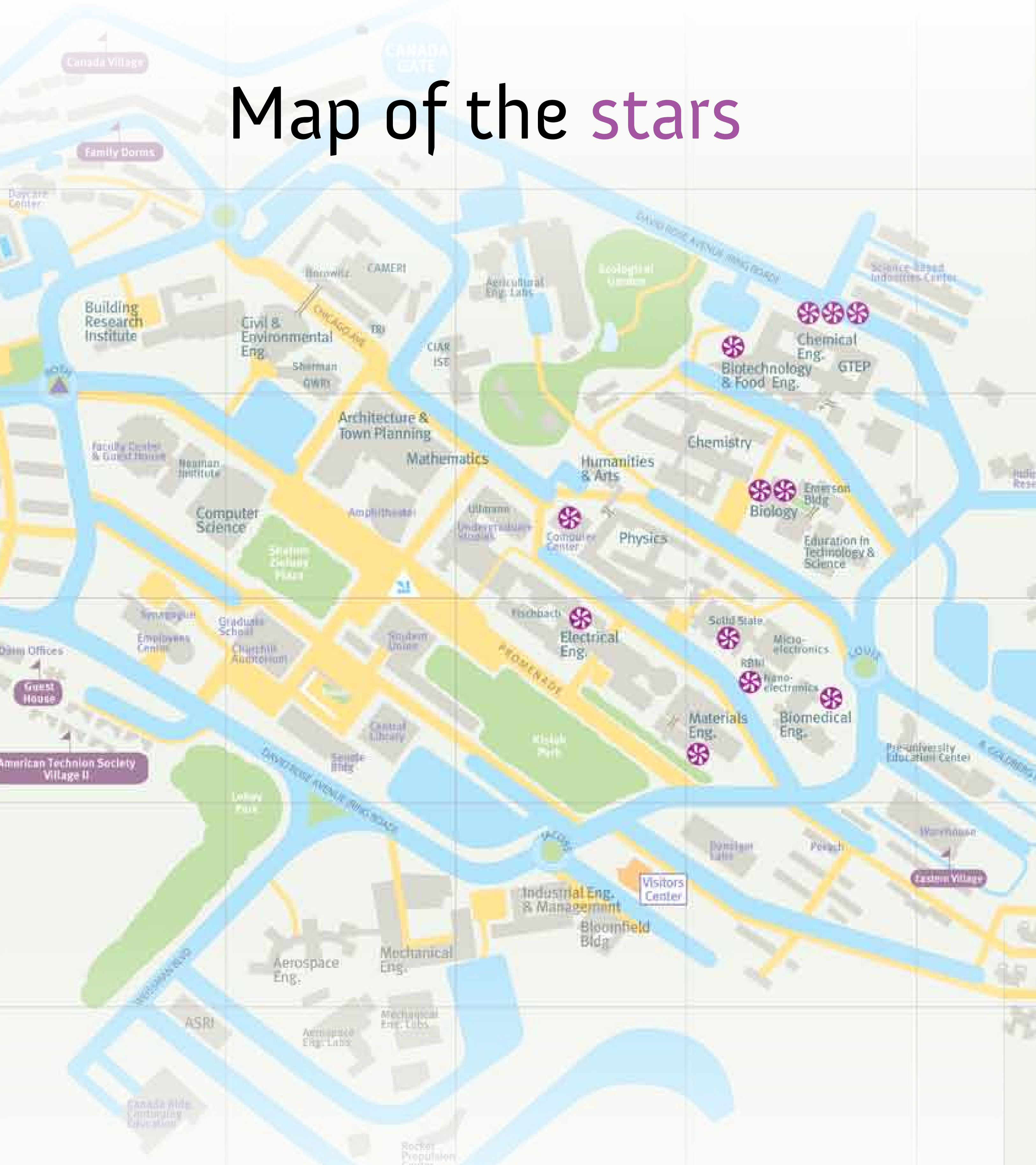
Tamnun "Octopus" supercluster

RBNI supported the installation of a new high performance computing cluster, an SGI-manufactured system known as "Tamnun" or Octopus. The system is Israel's fastest civilian cluster.

Tamnun consists of 88 computational nodes, each with a pair of 2.4 GHz, six-core Xeons and 96 GB of memory. Four servers have been equipped with NVIDIA Tesla M2090 GPUs. Storage consists of 28 nodes equipped with 500 GB drives, 52 nodes with 1 TB SATA drives, and 4 nodes with 1200 GB SAS drives. Everything is stitched together via InfiniBand, but the management network communicates over a couple of GigE switches.

The purchase and installation of the Tamnun cluster was partially funded by the Minerva Foundation.

Map of the stars



Nano Facilities

Micro and Nanofabrication Unit (MNFU)
Electrical Engineering
The center was built and equipped with state of the art clean-rooms and individual labs. The Zisapel Center complements the Wolfson Microelectronics Center with approximately 700 m² of clean-rooms.

Electron Microscopy
Materials Science and Engineering
The center includes a top-of-the-line Transmission Electron Microscope (TEM) (0.07 nm resolution) also called Titan, an additional TEM, Environmental Scanning Electron Microscope (ESEM), new Zeiss Ultra Plus high-resolution SEM and a FEI T20. The center also includes advanced facilities for sample preparation, including a Dual Focused Ion Beam (FIB) system.

Electron Microscopy for Soft Matter
Chemical Engineering
A center for direct imaging of liquid nanostructured system.
The center has two cryo-TEMs and a high-resolution cryo SEM. Advanced cryo-specimen preparation equipment is also available, including equipment for Freeze-fracture-replication (FFR) and cryo-microtomy.

Surface Characterization Center
Solid State Institute
A research & service laboratory for surface thin film analysis. The center includes a UHV Scanning Tunneling Microscope (STM), Near Field Scanning Optical Microscope (NSOM), and Time of Flight Secondary Ion Mass Spectroscopy (TOFSIMS).

X-ray and Particle Characterization Facilities
Chemical Engineering
The x-ray and particle characterization facilities mainly focuses on small-angle x-ray scattering (SAXS), a well-established technique for studying structural features of colloidal or Nanometric dimensions (1-100 nm). Appropriate analysis of SAXS data can provide wealth of structural information such as size, shape, internal structure and mass of particles, degree of agglomeration or superstructure, particle size distribution in polydispersed systems, and fractal dimensions in disordered systems. The center also offers equipment for x-ray diffraction.

Nanophotonics facility
Electrical Engineering
The facility offers advanced instrumentation for spectroscopy, nonlinear optics, high speed devices, ultrafast optics and high spatial resolution characterization – to the nanometer regime. It serves faculty members and tens of graduate students as well as several post docs and research associates.

Life Sciences & Engineering Center (NanoMed Project)
In Emerson Building
RBNI has teamed up with the Lorry I. Lokey Interdisciplinary Center for Life Sciences and Engineering to set up an infrastructure center for life sciences. Facilities include advanced light microscopy and cell sorting.

Tamnun Octopus Supercloster
Computer Center
High performance computing cluster, an SGI-manufacture system.

Biomechanics and Tissue Engineering Center
Biomedical Engineering
In cooperation with the Lorry I. Lokey Center, RBNI has invested in equipment facilitating advanced mechanical characterization and manipulation of tissue and tissue scaffolds, and bio-rheology

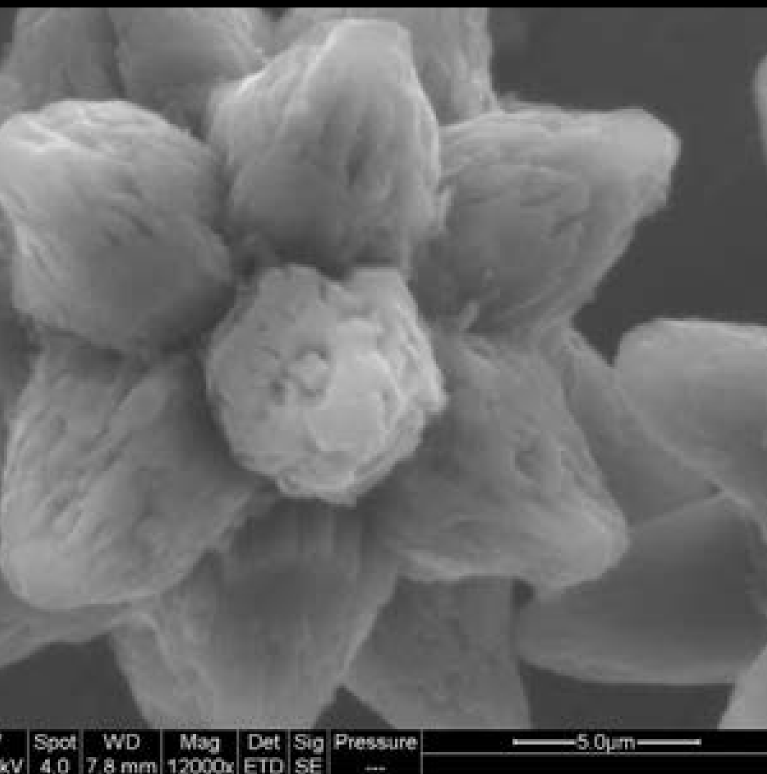
Joint GTEP & RBNI Technion Photovoltaic Laboratory
Zisapel Building
The center was established to provide basic and advanced tools for the fabrication and characterization of photovoltaic devices.

The Russell Berrie Nanoparticles and Nanometric Systems Characterization Center
Chemical Engineering
Biotechnology & Food Engineering
Colloidal and molecular characterization equipment has been grouped under one roof and supplemented with dynamic and static light scattering capabilities, Atomic Force Microscope (AFM), as well as spectrofluorometry capabilities in solution.

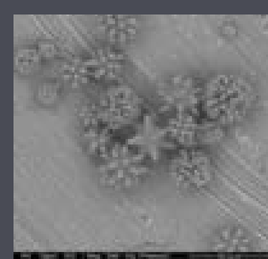
Smoler Proteomics Center (NanoMed Project)
Biology
The Center is the Israeli national infrastructure hub for proteome analysis.

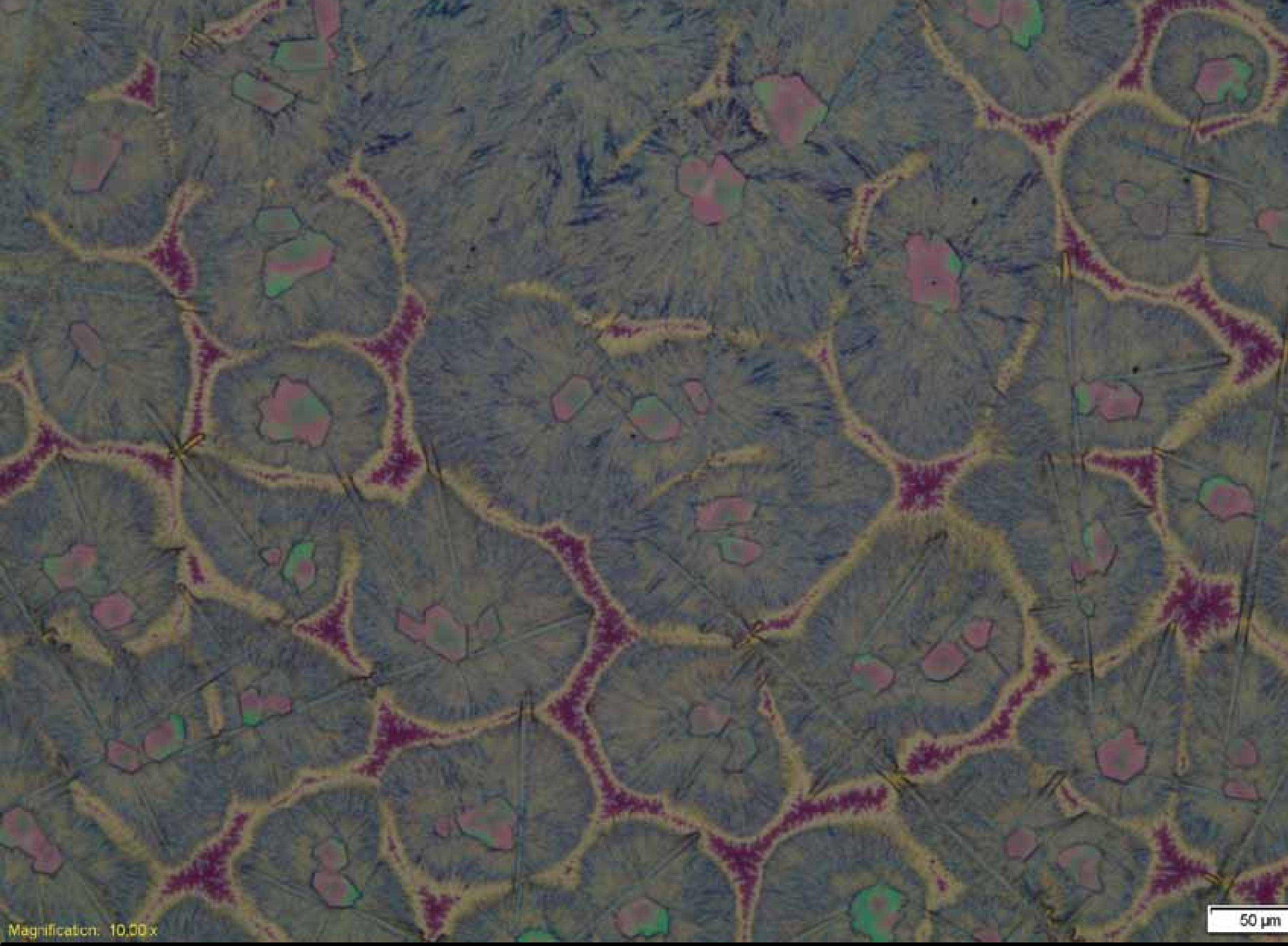
For additionnal information:
http://rbni.technion.ac.il

Technion Pananorama



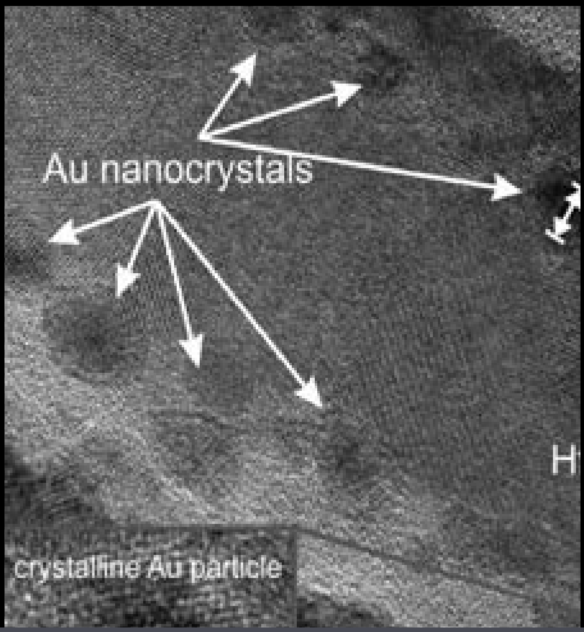
Anastasia Brif, a student in Assis. Prof. Boaz Pokroy's group at the faculty of Materials Science & Engineering: Didemnidae aragonitic spicules

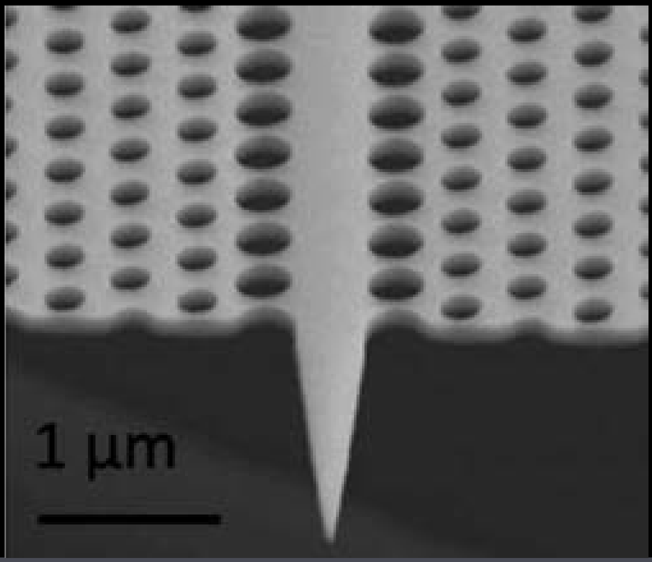




Maria Koifman, a student in Assis. Prof. Boaz Porkoy's group: Silicon single crystals formed from a silicon-gold eutectic thin film.

Technion Pananorama



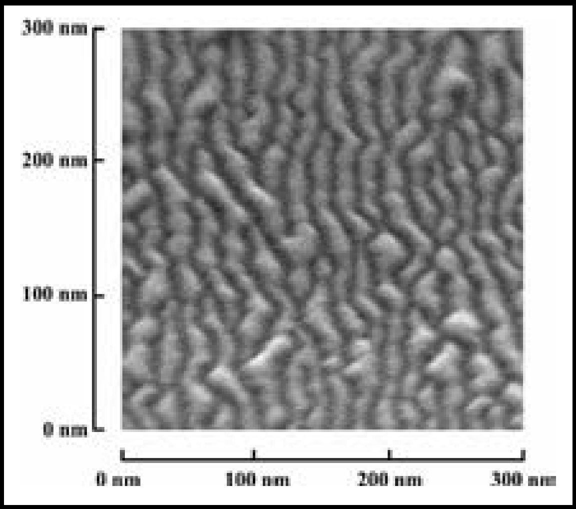


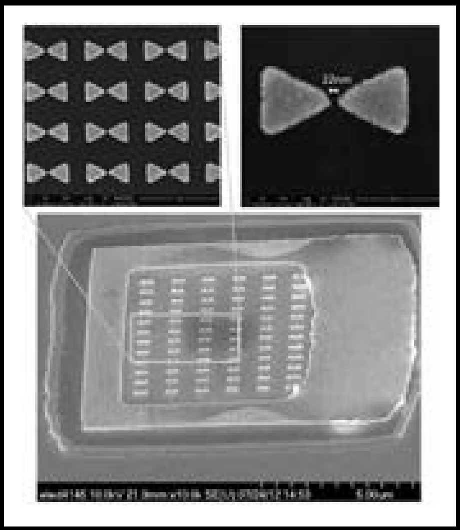
Silicon Nonvolatile memory based on Gold nano particles. Produced at the Technion MNFU by Dr. Beso Mikhelashvili and Dr. Boris Mayler from the MNFU. The HRTEM was taken in Prof. Wayne Kaplan's lab.

GaInP Photonic crystal waveguide with mode convertor by Isabelle Cestier from Prof. Gadi Eisenstein's group. Fabricated in collaboration with Thales France.

InAs quantum dash material fabricated by Prof. Gadi Eisenstein in collaboration with Kassel University, Germany.

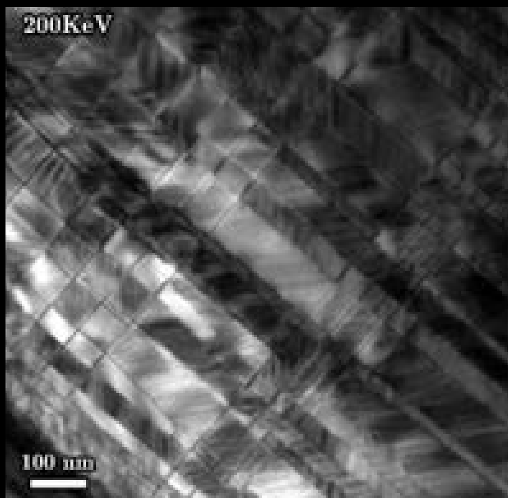
Fast light emitting diode (LED) by nano plasmonic antennas. Produced at the Technion MNFU by Prof. Meir Orenstein's group.

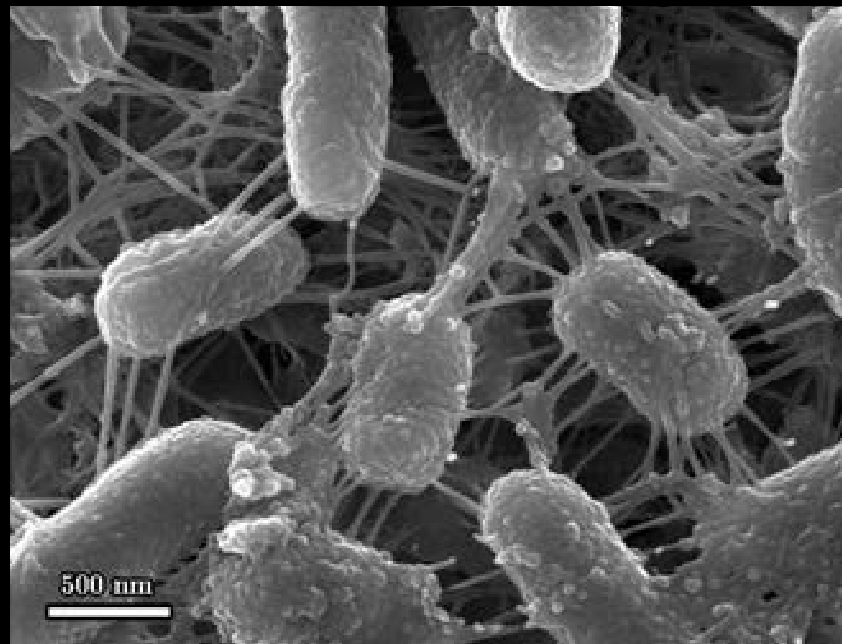




"We think that the biggest breakthroughs in nanotechnology are going to be in the new materials that are developed."

- Troy Kirkpatrick, GE Global Research.



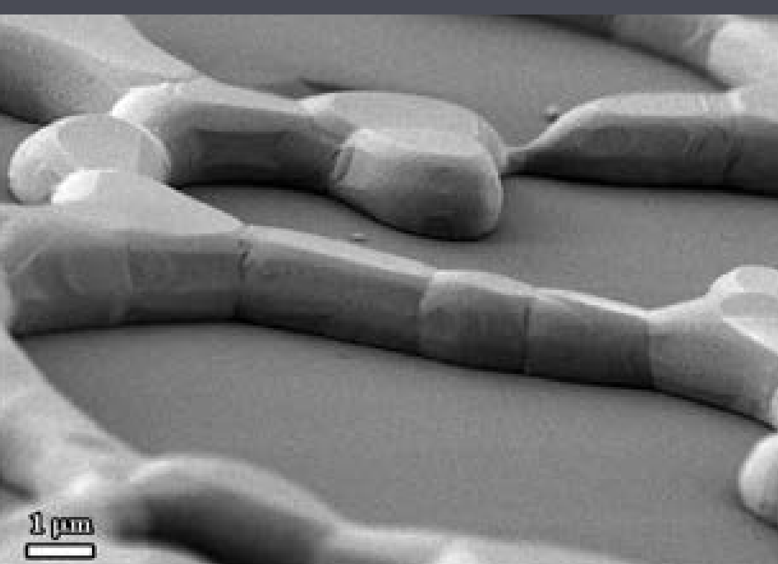


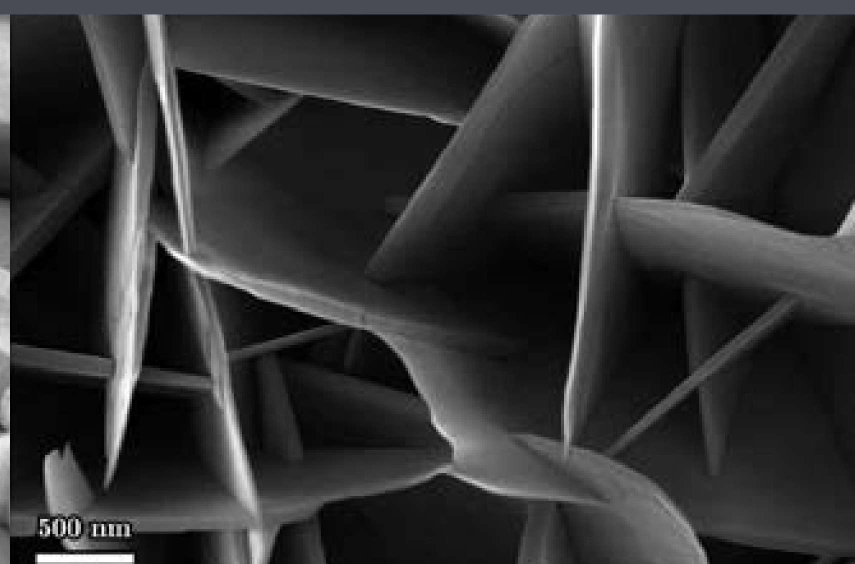
An array of twins in ScAl. Acquired using the Tecnai T20 by Maya Kedem of Distinguished Prof. Dan Shechtman's group.

A biofilm of Pseudomonas Putida (6 days old) developed on a PVDF ultrafiltration membrane. Acquired using the LEO by Dr. Alex Brener and Lior Eshed.

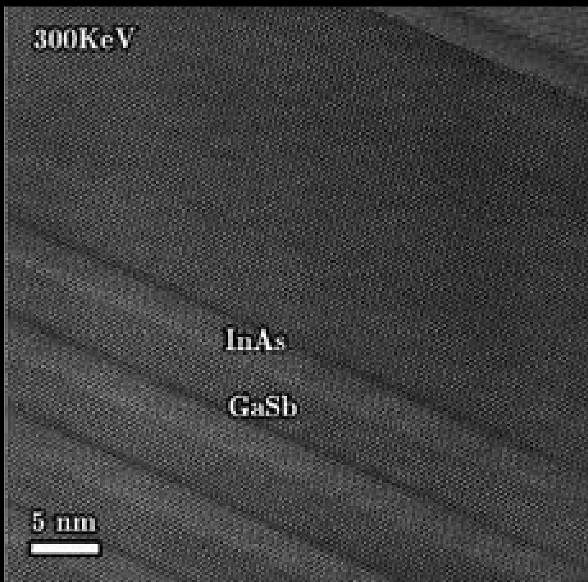
Dewetting of Ni on sapphire. Acquired using the LEO by Amir Avishai of the Prof. Wayne D. Kaplan group.

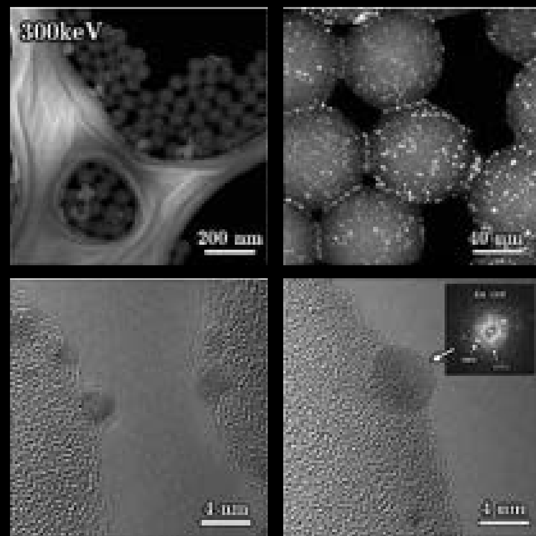
Top view of a biomimetic calcium-phosphate coating on a Ti implante. Acquired using the LEO by Tal Reiner of Prof. Elazar Y. Gutmanas and Irena Gotman group.





Technion Pananorama



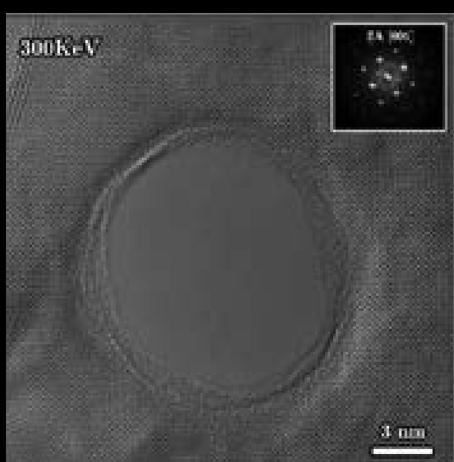


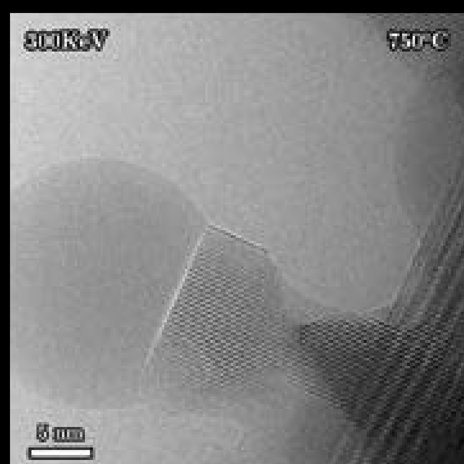
Cs corrected HRTEM micrograph of a super lattice of GaSb-InAs. Acquired using the Titan by Dr. Yaron Kauffmann and Hezi Ashuach (Prof. Emil Zolotoyabko).

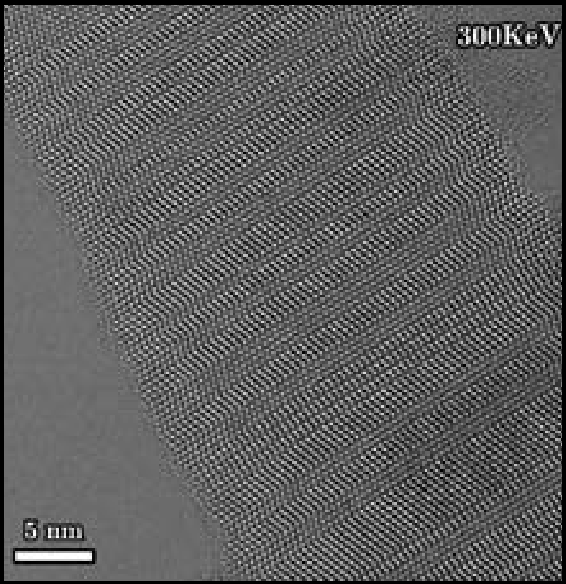
HAADF STEM and HRTEM micrographs of Pt nano-particles on polystyrene spheres. Acquired using the Titan by Dr. Yaron Kauffmann and Marc Schrinner (Prof. Ishi Talmon).

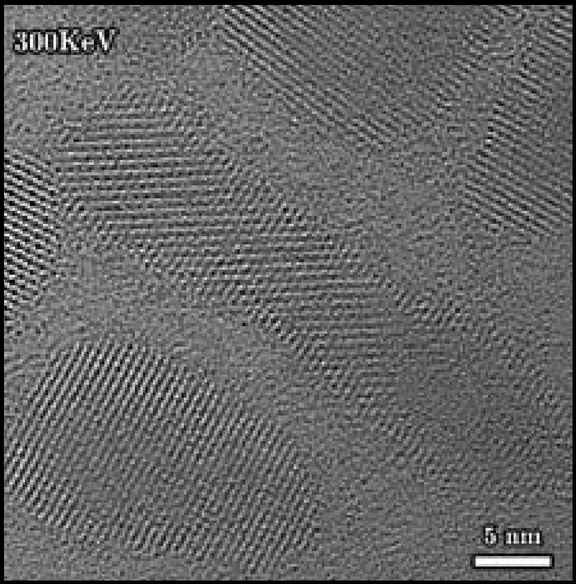
Reconstructed HRTEM image of a hole drilled in a Si substrate using a converged electron beam. Drilled and acquired using the Titan by Miri Drozdov (Prof. Wayne D. Kaplan).

HRTEM image of a liquid Al drop on a sapphire substrate at 750°C. Acquired using the Titan by Dr. Yaron Kauffmann and Miri Drozdov (Prof. Wayne D. Kaplan).









InP nanowire produced in Prof. Dan Ritter's lab.

HRTEM image of a $PbSe_{1-x}S_x$ core-shell nano-rod. Acquired using the Titan by Dr. Yaron Kauffmann and Gary Zaiats (Prof. Efrat Lifshitz).

Dendrite of magnesium Grown on Mg alloy surface from vapor phase. Acquired using the LEO by Sergei Remennik of Distinguished Prof. Dan Shechtman's group.

Graphite cylinders on amorphous carbon film. Acquired using the Titan by Dr. Yaron Kauffmann.