

INSTITUTE 20YRS RUSSELL BERRIE NANOTECHNOLOGY

Think Small.
Dream Big.


10 μm



TECHNION



Russell Berrie
Nanotechnology Institute



***RBNI has proven to be more than just
a resource; it has become a catalyst for
discovery, safeguarding research against global
uncertainty and empowering bold scientific
ideas to become reality.*** – Prof. Charlotte Vogt

Pictured on front cover:
Gold nano ribbon
Created by Dr. Larisa Popilevsky,
FIB Lab Manager

Pictured on inside cover:
Nano scaffold



Think Small. Dream Big.

The Russell Berrie Nanotechnology

Institute at Technion 2005-2025

20 years forward



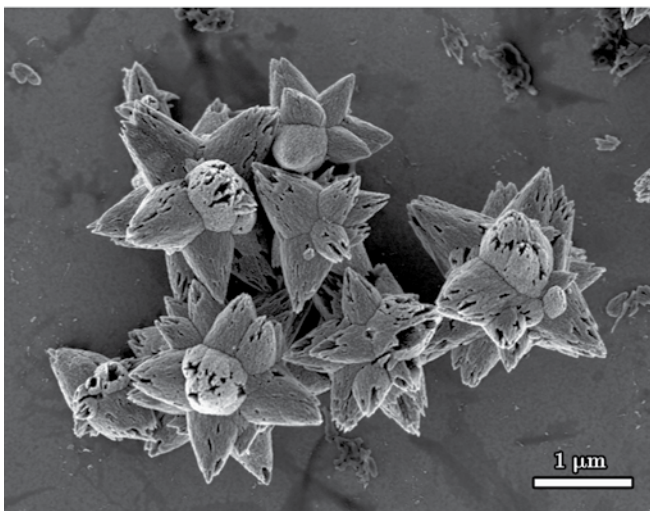
Russell Berrie
Nanotechnology Institute

INSTITUTE 20YRS RUSSELL BERRIE
TECHNOLOGY NANOTECHNOLOGY

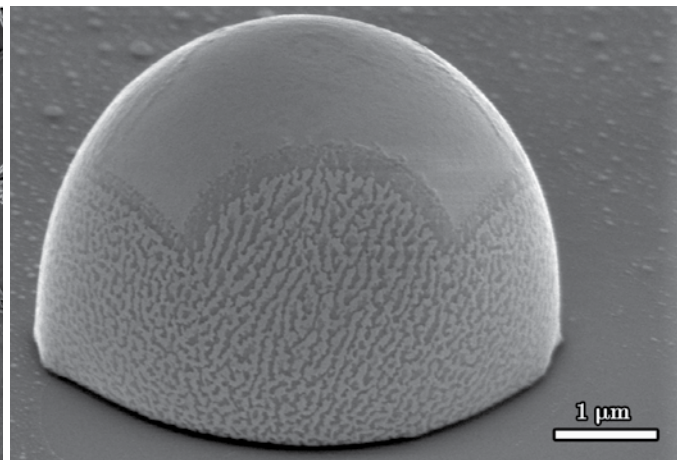
Think Small.
Dream Big.

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The Russell Berrie Nanotechnology Institute (RBNI), Israel's first and largest institute for nanotechnology research, celebrates 20 years of frontier science. The Institute that garnered crucial support from the Russell Berrie Foundation, the Government of Israel, and Technion became a model for research initiatives in Israel and internationally. The Institute brought together researchers from 14 faculties, over 2,000 undergraduate and graduate students, and is an engine for innovation and breakthrough research, shaping a future where the tiniest innovations make the biggest impact.



SEM micrograph of ZnO crystals. Acquired using the Zeiss Ultra by Anastasia Brif (Boaz Pokroy)



SEM micrograph of a gold curved single crystal in a droplet of eutectic Au-Ge phase. Acquired using the Zeiss Ultra+ by Maria Koifman (Boaz Pokroy)

From the Technion President

“The institute became a national beacon.”

It is a privilege to celebrate the twentieth anniversary of the Russell Berrie Nanotechnology Institute, an achievement that reflects vision, collaboration, and a shared belief in the transformative potential of science. Looking back, I recall the early 2000s, when the global community recognized that nanotechnology would be central to advances in medicine, energy, information technology, and environmental sustainability. It was clear that for Israel to participate fully in this emerging frontier, bold action was required.

At Technion, we embarked on an ambitious plan to unify our efforts across disciplines, culminating in the creation of the Technion Campuswide Program in Nanoscience and Nanotechnology. Together with colleagues, we mapped the campus’s capabilities, developed a comprehensive vision, and began building the foundations of what would become RBNI. These early steps brought together researchers from physics, chemistry, engineering, life sciences, medicine, and computer science, forging a multidisciplinary community dedicated to exploration and innovation.

The establishment of RBNI in 2005 was made possible by a remarkable partnership with The Russell Berrie Foundation. Their support, combined with matching commitments from the government and Technion, created a model of collaborative investment that remains unique. The Foundation’s trust and vision enabled us to build infrastructure, recruit talented faculty, and set the institute on a path of lasting impact — not only within the Technion, but across Israel’s national research landscape. Over the first decade, the Institute managed more than \$130 million in resources, supported the creation of tens of startups, and contributed to the awarding of hundreds of patents, while training thousands of graduate students.

Beyond metrics, RBNI transformed the culture of Technion. It broke down barriers between faculties, nurtured interdisciplinary collaboration, and inspired a generation of scientists and engineers to engage with challenges that span disciplines. The Institute became a national beacon, catalyzing similar efforts in other universities and shaping Israel’s broader commitment to nanoscience and technology.

As we look ahead, RBNI continues to embrace new frontiers. The questions we tackle today — in quantum technologies, advanced materials, energy, and health — demand the same combination of vision, rigor, and collaboration that marked our beginnings. The Institute’s mission remains to advance basic science, translate discoveries into applications, and educate the next generation of researchers who will carry Israel and the world forward.

This anniversary is not only a moment to honor the achievements of the past, but to reaffirm our dedication to the future. To The Russell Berrie Foundation, to our faculty, students, staff, and partners — thank you. Your partnership, creativity, and commitment have made RBNI what it is today: a hub of discovery, innovation, and national pride.

May the coming years continue to build on this foundation, inspiring scientific excellence, fostering collaboration, and demonstrating how strategic vision and partnership can change the landscape of research, education, and society.

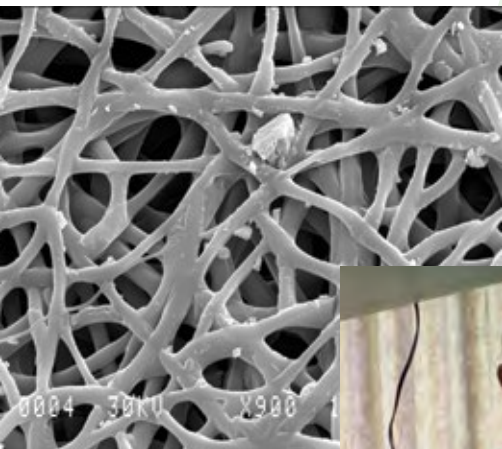


Prof. Uri Sivan
Technion President
RBNI Founding Director



Prof. Uri Sivan stands in front of the Technion time capsule on the Zielony Plaza, just meters from the Calatrava Obelisk—erected in 2009 in the heart of the campus to mark the establishment of the Russell Berrie Nanotechnology Institute. The capsule contains milestones from Technion’s more than century-long history, and notably, the Nano Bible.

From the RBNI Director: History and Impact



Prof. Gadi Eisenstein



Technion was the first Israeli university to recognize the upcoming nano revolution. Following its long tradition of pioneering large-scale programs that influence the economy and security of the nation, Technion took upon itself to start the Israeli nano science and technology revolution.

In the late 1990s, the global scientific community recognized nanotechnology's emerging potential to revolutionize information and computing technologies, healthcare, energy, and environmental sustainability. This trend was initially led by engineers engaged in advanced electronics where nano scale devices were already being produced routinely, by physicists and chemists. What was missing at that time was the immense advantage of multidisciplinary research that nano science and technology offered. The emerging field of nanotechnology brought together scientists from vastly diverse disciplines, leading to numerous breakthroughs impacting the scientific community and ultimately the public at large.

Technion was the first Israeli university to recognize the upcoming nano revolution. Following its long tradition of pioneering large-scale programs that influence the economy and security of the nation, Technion took upon itself to start the Israeli nano science and technology revolution. Historic examples at Technion include the establishment of the aeronautics department, the microelectronics center—considered the cradle of Israel's high-tech industry, the medical school, and the Seiden Optoelectronics Center.

In 2001, a comprehensive plan for a Technion Program in Nanoscience and Nanotechnology was drawn up by a team of faculty members led by Profs. Uri Sivan, Efrat Lifshitz and Nir Tessler. They envisioned a new model for a research institute that unified nanoscience-related faculty members from many departments within a collaborative framework. The vision laid out fundamental principles, the most important being that the Institute would be distributed across campus, comprising many infrastructure centers, each located in the most appropriate department. Each infrastructure center would be managed locally, while the Institute management would fund major equipment and operating costs. It was also decided that the Institute would establish a graduate studies program, which evolved into the Norman Seiden Multidisciplinary Graduate Program in Nanoscience and Nanotechnology, the only accredited nano studies program in Israel.

The plan was swiftly adopted by Technion management, and a major effort was initiated to raise funds to cover the significant cost of such a program. A decisive moment came in 2004 when the Russell Berrie Foundation committed a transformational gift to establish the Institute, contingent on matching funds from the Israeli government and Technion. This led to an historic \$78 million initial investment, setting a precedent known as the triple



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Yana Milyutin in the 2D Center

funding model. The Israeli government recognized the unique opportunity and provided its share, and Technion followed with its own contribution. This paved the way to the launch of the Russell Berrie Nanotechnology Institute (RBNI) in 2005, with Prof. Sivan as its founding director. RBNI's funding soon surpassed the \$100M mark, becoming the largest academic program in Israeli history.

The requirement that the Israeli government match the Russell

Berrie Foundation's donation had a nationwide impact leading to the establishment of five more nano centers. Within less than a decade, Israel became an empire in nano science and technology.

A national committee for planning nano activities in Israel was first established in 2003. Four years later, in 2007, the government established the Israel National Nano Initiative (INNI), an international supervisory committee that accompanied the nano developments

in all Israeli universities influencing nano research nationwide.

In 2012, the government announced a nationwide call for a second round of competitive funding in nanotechnologies titled Focused Technology Areas (FTA), addressing the various sub-fields of nanotechnology. RBNI won the largest share of the FTA budget, receiving \$10M focused on nanophotonics. These funds further developed RBNI's infrastructure, highlighted by the purchase of a state-of-the-art

Electron Beam Writer, which allowed RBNI's researchers to compete with any top university worldwide.

An international advisory committee, headed by Dr. Dan Maydan (the founder of Applied Materials), recommended that RBNI enter the important area of two-dimensional (2D) materials and devices. This required a substantial investment in new equipment and a specialized environment, for which the Russell Berrie Foundation graciously provided RBNI with a \$2.5 million grant dedicated to 2D research equipment. The new 2D Center, which has already achieved significant success was officially inaugurated in May 2024, during a prestigious conference held at Technion.

Implementing the Vision

RBNI transformed the Technion campus in numerous ways, the most vivid example being the breakdown of traditional barriers between faculties and disciplines. This led to the establishment of a large and diverse nano community, which nurtured a dynamic and cohesive group of researchers and graduate students, resulting in a remarkable number of new collaborative research directions. RBNI provided an overarching management structure that supports the hiring of young, talented faculty. It facilitated access to numerous funding channels including seed money for selected revolutionary ideas, support for equipment-use charges, training, conference organization, and student travel to conferences. It also fostered the commercialization of research findings, patent submissions, and technology transfer.

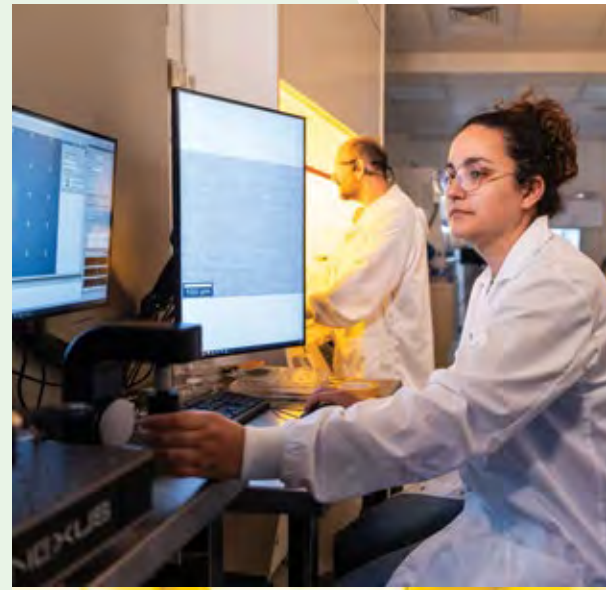
RBNI recruited over 25 superstar new faculty members, helping Technion with the startup packages enabling

construction of fully equipped research laboratories. The Institute established and supported 19 infrastructure centers with an investment in equipment exceeding \$100 million.

Today, the RBNI multidisciplinary community embraces some 200 faculty members and researchers, as well as hundreds of graduate students and postdocs from 14 faculties. RBNI researchers are global leaders in the fields of nano photonics, nano materials, nanomedicine, and environmental sustainability.

Academic Program

RBNI established the only accredited educational program in Israel granting advanced degrees in nanoscience: the Norman Seiden Multidisciplinary Graduate Program in Nanoscience and Nanotechnology. This program has established itself as a prestigious graduate program attracting outstanding students from diverse backgrounds. Many graduates pursue academic careers, while most hold key positions in Israeli high-tech, biomedical, and defense industries. The program provides attractive fellowships and grants, annually awarding fellowships and prizes to top students.



Today, the RBNI multidisciplinary community embraces 200 faculty members and researchers, as well as hundreds of graduate students and postdocs from 14 faculties.



Pictured above: Norman Seiden presents graduate student Hen Dotan with an RBNI Excellence Scholarship in 2013. Dotan later co-founded H2PRO, where he is CTO, promoting sustainable hydrogen fuel.



Pictured below: Norman Seiden presents graduate student Tamar Segal-Peretz with an RBNI Excellence Scholarship in 2012. Today, Segal-Peretz is a professor in the Faculty of Chemical Engineering and a member of RBNI.

RBNI researchers are global leaders in the fields of nano photonics, nano materials, nanomedicine, and environmental sustainability.

Outreach

The Institute fosters extensive collaborations with international nano centers. At the same time, RBNI supports extensive collaborations and partnerships with Israeli industries. The research at RBNI has yielded over the years a massive quantity of intellectual property that benefits Technion via the Technion Research and Development Foundation.

RBNI has established a tradition of winter schools, held off campus, which host some 150 graduate students, including students from all Israeli universities and overseas. The lectures are given by leading experts from Israel and around the world. RBNI also established specialized symposia with German universities funded by the Reinhard Frank Foundation. The first three years of the program covered the Green Internet, and a second ongoing program focuses on Quantum Technologies.

Additionally, RBNI hosts international conferences, and has developed educational activities and high-school outreach programs to attract and inspire the next generation of scientists.

National and Global Influence

As RBNI marks twenty years of excellence, we reflect with pride on how the founding vision has not only been realized but exceeded expectations. RBNI is recognized worldwide as a major research and education center in nano science and technology. Technion nano research students often pursue postdoc positions at prestigious universities in the USA and Europe, and most return to Israel to assume faculty positions. Other graduates take up prominent positions in industry or create startups.

RBNI researchers are considered world leaders, and are part of a handful of researchers who set the scientific agenda for the global nano science and technology community.

The success of RBNI served as a cornerstone for the latest Technion mega program: The Helen Diller Quantum Center. Quantum activities gained momentum at Technion in 2016, and by 2018 a transformational gift from the Helen Diller Foundation has allowed Technion to become a leading player in the quantum field. Quantum science and technology is a key global research

topic with the largest international tech companies and top universities investing in massive programs in quantum computing, communication, sensing, and materials. Research comprises three main directions: theory, quantum experimental research in hot and cold atoms, and quantum devices in solid state materials, mainly semiconductors. RBNI's state-of-the-art infrastructure and expertise power Technion's experimental research in quantum science and technology, driving breakthroughs that redefine the limits of possibility. RBNI members are also key figures in the Helen Diller Quantum Center. These two flagship centers work in synergy, united by a shared long-term vision.

Prof. Gadi Eisenstein
RBNI Director

RBNI Administration
<p>Directors Prof. Gadi Eisenstein 2013- Prof. Ishi Talmon 2010-2012 Prof. Uri Sivan 2005-2009</p>
<p>Administration Tanya Ashkenazi Manager</p>
<p>Meirav Sondak-Minikes Projects Head</p>
<p>Pazit Savyon Projects Head</p>

From The Russell Berrie Foundation President



The Russell Berrie Foundation trustees at the festive dedication ceremony of RBNI in 2005. (l-r) Prof. Yitzhak Apeloig, Norman Seiden, Foundation President Angelica Berrie, Ilan Kaufthal, Scott Berrie, and Myron Rosner.

Twenty years ago, The Russell Berrie Foundation made a transformative investment in Technion to establish the Russell Berrie Nanotechnology Institute (RBNI). This bold step launched a new frontier for Israel in the emerging field of nanotechnology.

We mark RBNI's 20th anniversary as The Russell Berrie Foundation celebrates forty years of impact. Inspired by Technion's historic role in shaping Israel's growth, we set out to help secure the nation's future by positioning Israel as a global leader in nanoscience.

Our \$26 million founding gift, matched by the Israeli government and Technion, created Israel's first philanthropic-government-academic partnership of its kind. Together, we built a catalyst for groundbreaking research addressing humanity's most urgent challenges, from curing disease to advancing sustainable energy and strengthening Israel's security.

This unique three-way collaboration was rooted in the entrepreneurial spirit of our founder, Russ Berrie, whose love for Israel and belief in possibility fueled the vision behind RBNI.

In the years since, this model of collaborative philanthropy has helped spur the development of a national nanotechnology ecosystem. Today, it encompasses a \$250 million research platform with more than 150 faculty members and 300 graduate students and postdoctoral fellows across 14 faculties. RBNI became a forerunner of Israel's innovation

landscape, paving the way for nanotechnology centers nationwide and attracting visionary minds whose work continues to shape the future and impact humanity on a scale we could not have imagined when we first began.

Looking back, certain moments stand out. I was deeply moved when President Shimon Peres presented a nano-Bible from RBNI to Pope Benedict as a gift from the Jewish people on his first official visit to Israel. And I felt immense pride when another nano-Bible traveled into space—an extraordinary symbol linking scientific achievement with our Jewish heritage.

The most fulfilling part of this twenty-year journey has been witnessing the accomplishments of RBNI's researchers, whose discoveries will benefit humanity for generations. As we celebrate this milestone, we honor their brilliance and reflect on how a nano-seed of an idea became a launchpad for Israel's leadership in a field that continues to transform our world.

Angelica Berrie

Angelica Berrie

The Russell Berrie Foundation President



The Russell Berrie Foundation was created in 1985 by entrepreneur and philanthropist Russell Berrie. Rooted in Russ's conviction that "there is nothing more important in life than helping a fellow human being," the foundation approaches philanthropy as transformational giving to exceptional leaders—treating grants as social investments in people and ideas with the potential to change systems, not just support programs.

With a focus on New Jersey and Israel, the foundation identifies visionary institutions, innovators, and "unsung heroes," and amplifies their work with financial resources and strategic partnership. Guided by Russ Berrie's founding mission, the foundation concentrates on several core areas: cultivating thriving Jewish communities, strengthening an inclusive and resilient Israel, driving breakthroughs in diabetes care, and building bridges across differences.

Now marking its 40th anniversary, The Russell Berrie Foundation is intentionally spending down its assets and will sunset in 2033. This planned conclusion reflects a "sunrise" strategy: to use its remaining years to strengthen the organizations, communities, and ideas it has championed so that, long after the foundation closes its doors, its partners are better equipped to make a lasting difference in the world.



Russell Berrie (1993-2002), founder, chairman, and CEO of the celebrated gift company bearing his name, was one of the most innovative philanthropists of his generation. He took an entrepreneurial approach to philanthropy, using his keen interpersonal skills to identify people and causes in which to invest and working closely with partners to hone strategies and set expectations. "Russ had an amazing capacity to both envision the world as it could be and figure out how to collaborate with others to make it so," said Angelica Berrie, his wife and the President of the Russell Berrie Foundation.



The Russell Berrie Foundation trustees attended the 2009 dedication ceremony of the Obelisk, designed by architect Dr. Santiago Calatrava. (l-r) Scott Berrie, Norman Seiden, Ilan Kaufthal, Dr. Santiago Calatrava, Foundation President Angelica Berrie, Prof. Yitzhak Apeloig, Zipora Apeloig, Stephen Seiden, and Myron Rosner.



Angelica Berrie was awarded a Technion Honorary Doctorate in 2008 for her exceptional support of Technion and Israel.

RBNI in numbers

2005-2025

Over

2,000

GRADUATES IN NANOSCIENCE
AND NANOTECHNOLOGY FIELDS

19

INFRASTRUCTURE
CENTERS

200

FACULTY MEMBERS

25

FACULTY RECRUITS

212

GRADUATES OF THE NORMAN
SEIDEN MULTIDISCIPLINARY
GRADUATE PROGRAM
IN NANOSCIENCE AND
NANOTECHNOLOGY

Over

\$100M

INVESTMENT IN
EQUIPMENT

51

STARTUPS

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Dan Shechtman, Nobel Prize in Chemistry 2011

Select Awards

Erez Hasman

Henry Taub Prize for Academic Excellence, Technion
Fellow, Optical Society of America
Morton and Beverley Rechler Prize for Excellence in Research, Technion

Ido Kaminer

Member, Israel Young Academy
Lomb Medal, Institute of Physics (UK)
Blavatnik Award for Young Scientists

Wayne Kaplan

Robert B. Sosman Award, American Ceramic Society
Fellow, American Ceramic Society
Distinguished Lecturer, Case Western Reserve University

Roy Kishony

EMBO Membership, European Molecular Biology Organization
Sanofi - Institut Pasteur Award
Member, Israel Young Academy

Shulamit Levenberg

Fellow, American Institute for Medical and Biological Engineering
Fellow, National Academy of Inventors (USA)
Rappaport Prize for Excellence in Biomedical Sciences

Efrat Lifshitz

Fellow, Freiburg Institute for Advanced Studies, University of Freiburg
Israel Chemical Society Prize for Outstanding Scientist
Israel Vacuum Society Excellence Award for Research

Marcelle Machluf

Lighter of the Independence Torch, Israel's 70th Independence Day State Ceremony
Selected among the 60 most influential scientists in cancer therapy, Israel Ministry of Science and Technology
Juludan Research Prize for Outstanding Innovative Research

Avi Schroeder

Krill Prize for Excellence in Scientific Research, Wolf Foundation
Yanai Prize for Excellence in Academic Education, Technion
Alon Fellowship

Mordechai Segev

Arthur L. Schawlow Prize in Laser Science, American Physical Society
Israel Prize in Physics
Member, National Academy of Sciences (USA)
Member, Israel Academy of Sciences and Humanities

Yoav Shechtman

Krill Prize for Excellence in Scientific Research, Wolf Foundation
Young Investigator Prize and Medal, International Union for Pure and Applied Biophysics
Member, Israel Young Academy

Yeshayahu Talmon

Member, Israel Academy of Sciences and Humanities
Doctor of Science, honoris causa, University of Lund, Sweden
Overbeek Gold Medal, European Colloid and Interface Society
Graham Prize, Colloid-Gesellschaft - German Colloid Society

Charlotte Vogt

Clara Immerwahr Award
Beilby Medal
EuroTech Future Award

Nir Tessler

Fellow, Royal Society of Chemistry (UK)
Honorary Fellow, Chinese Chemical Society
Henry Taub Prize for Academic Excellence, Technion

Gadi Eisenstein

IEEE Photonics Society William Streifer Scientific Achievement Award
Foreign Member, Istituto Veneto di Scienze, Lettere ed Arti (Italy)
IEEE Fellow

David Gershoni

Quantum Devices Award, International Symposium on Compound Semiconductors
Landau Prize for Arts and Sciences (Physics)
Carl Friedrich von Siemens Research Award, Alexander von Humboldt Foundation

Gideon Grader

Grand Prix Scientifique, Fondation Charles Defforey - Institut de France
Stephanie L. Kwolek Horizon Prize, Royal Society of Chemistry (UK)
Eric and Sheila Samson Prime Minister's Prize for Innovation in Alternative Fuels (Israel)

Hossam Haick

Knight of the Order of Academic Palms (France)
MRS Impact Award, Materials Research Society (USA)
Humboldt Research Award, Alexander von Humboldt Foundation

Nano City



NANO Infrastructure Centers

- Electron Microscopy Center (EMC)
- Technion Center for Electron Microscopy of Soft Matter
- Life Sciences and Engineering Infrastructure Center
- Surface Characterization Center of the Solid State Institute
- 3D-Bioprinting Center for Printing Cells and Biomaterials
- Biomechanics and Tissue Engineering Center
- Center for Computational Nanoscience and Nanotechnology (TAMNUN)
- Focused Ion Beam
- Mass Spectroscopy Laboratory
- Quantum Matter Research (QMR) Center
- Technion Center for Structural Biology (TCSB)
- Technion Photovoltaics Laboratory
- Biomedical Core Facility
- Chemical and Surface Analysis Lab
- Russell Berrie Nanoparticles and Nanometric Systems Characterization Center (NNSCC)
- Smoler Proteomics Research Center
- Sara and Moshe Zisapel Nanoelectronics Center (MNFU)
- 2D Center
- X-ray Lab



NANO Faculties

- Aerospace Engineering
- Biology
- Biomedical Engineering
- Biotechnology and Food Engineering
- Chemical Engineering
- Chemistry
- Civil and Environmental Engineering
- Computer Science
- Electrical and Computer Engineering
- Materials Science and Engineering
- Mathematics
- Mechanical Engineering
- Medicine
- Physics



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Civil & Environmental Engineering Faculty

Taub Computer Science Faculty

Mathematics Faculty

Taub Computer Ctr.

Viterbi Electrical and Computer Engineering Faculty

Physics Faculty

Rosen Solid State Institute

Materials Science & Engineering Faculty

Aerospace Engineering Faculty

Mechanical Engineering Faculty

Wolfson Faculty of Chemical Engineering

Biotechnology & Food Engineering Faculty

Schulich Chemistry Faculty

Emerson Family Life Science & Engineering Bldg.

Biology Faculty

Wolfson Microelectronics Ctr.

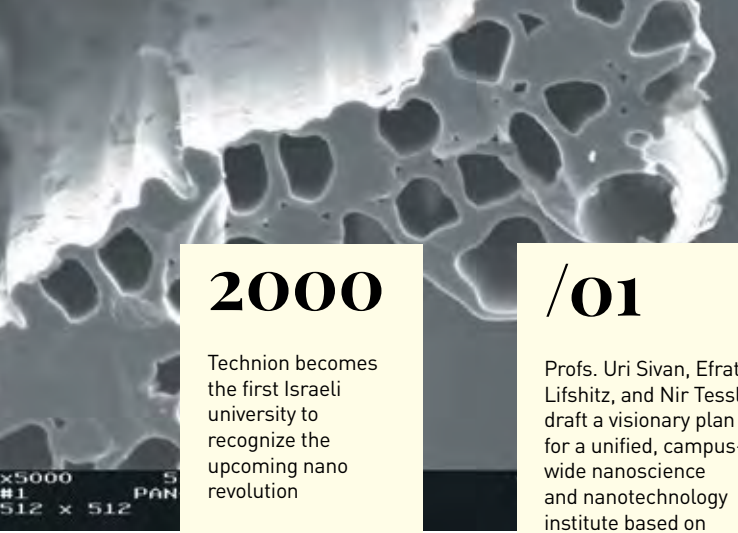
Zisapel Nanoelectronics Ctr.

Biomedical Engineering Faculty



Nano Milestones

2000 - 2025

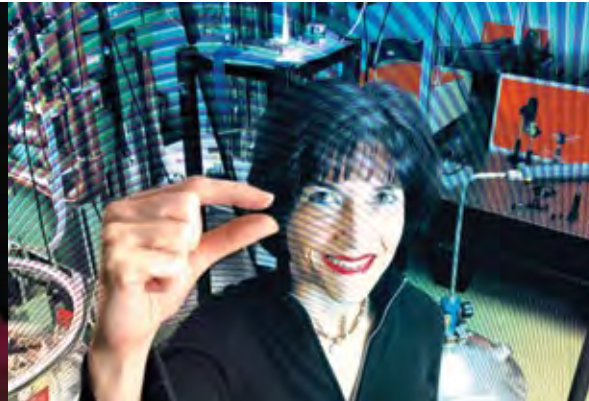


2000

Technion becomes the first Israeli university to recognize the upcoming nano revolution

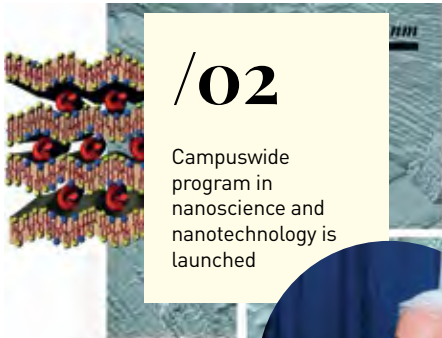
/01

Prof. Uri Sivan, Efrat Lifshitz, and Nir Tessler draft a visionary plan for a unified, campus-wide nanoscience and nanotechnology institute based on multidisciplinary collaboration



/02

Campuswide program in nanoscience and nanotechnology is launched



/03

Israeli Government establishes committee for planning a national nano research program



/04



Russell Berrie Foundation commits a transformational gift to establish the Institute, marking a defining moment in its creation

/05 RBNI Opens!

Russell Berrie Nanotechnology Institute (RBNI) opens with Prof. Uri Sivan as founding director

Phase I begins - focusing on research Infrastructure and graduate studies

Norman Seiden Multidisciplinary Graduate Program in Nanoscience and Nanotechnology is launched

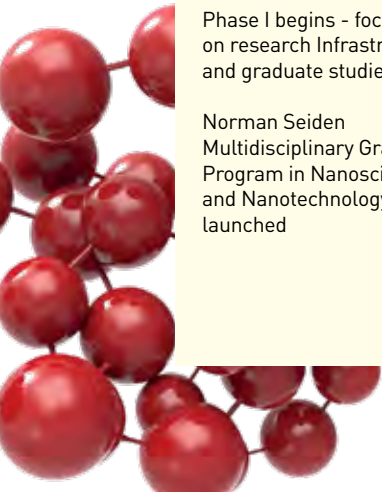


RBNI

/06

RBNI's funding surpasses \$100M, becoming the largest academic program in Israeli history

World's most advanced Titan transmission electron microscope arrives at Technion



/07

Government establishes the Israel National Nano Initiative (INNI)

Nano Bible is created as a tool to inspire high-school students to explore nanotechnology

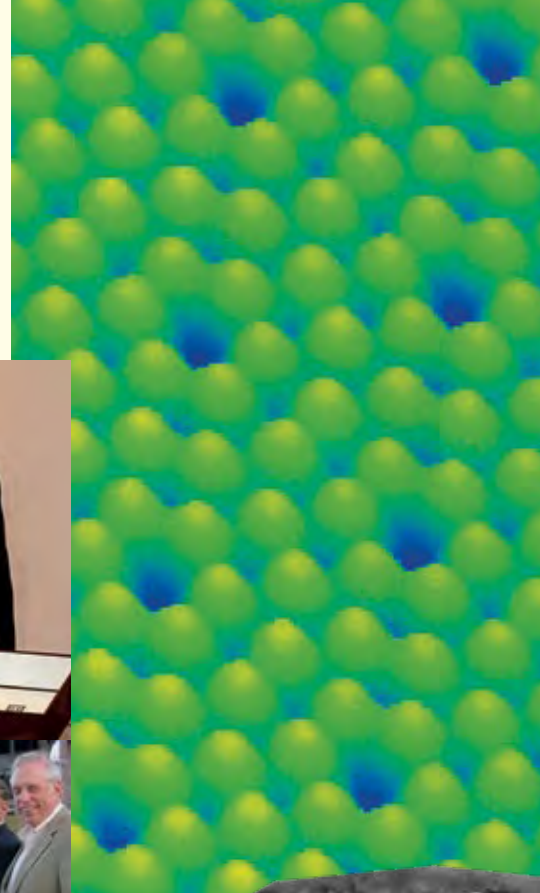
Dedication of Sara and Moshe Zisapel Nanoelectronics Center, a gift from Technion alumni Yehuda and Zohar Zisapel



/08

Angelica Berrie awarded a Technion Honorary Doctorate for her exceptional support of Technion and Israel

First of the renowned RBNI Winter Schools is held, exposing Israel's graduate students to the latest developments in nanotechnology



/09

President Shimon Peres presents Nano Bible to Pope Benedict XVI during his historic pilgrimage to Israel

Obelisk designed by Santiago Calatrava is erected at the heart of Technion campus in recognition of the Russell Berrie Foundation transformational gift



/10

Prof. Ishi Talmon appointed RBNI Director

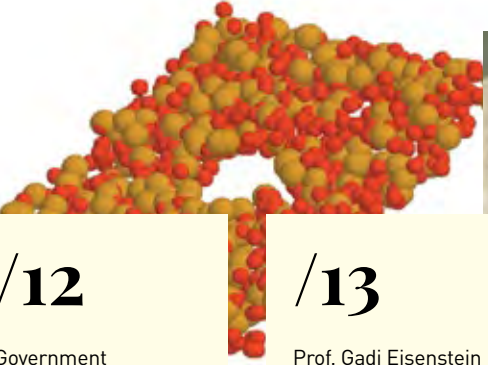
Phase 2 begins - expanding nanomedicine, energy, self-assembled structures, and photovoltaics research



/11

Prof. Dan Shechtman wins the Nobel Prize for the discovery of quasicrystals





/12

Government grant of \$10 M for nanophotonics research

A state-of-the-art Electron Beam Writer is acquired

/13

Prof. Gadi Eisenstein appointed RBNI Director



/14

The first Annual Green Photonics Symposium held at RBNI, supported by the Reinhard Frank Foundation



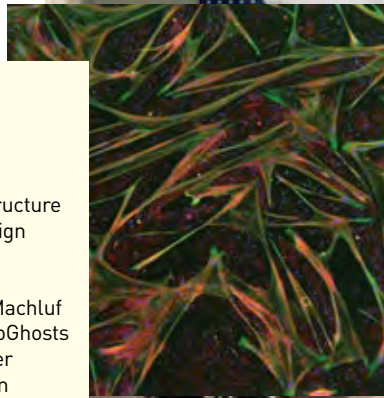
/15

Phase III begins - expanding into quantum science, quantum matter, and quantum engineering research

/16

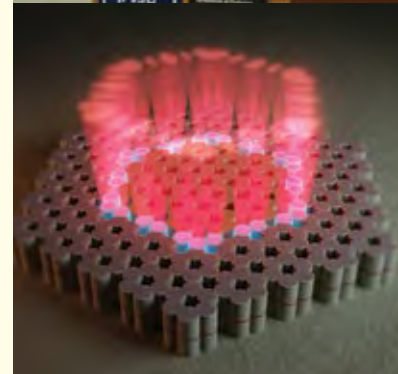
Massive infrastructure upgrade campaign launched

Prof. Marcelle Machluf introduces NanoGhosts as a novel cancer therapy platform



/18

Two back-to-back Science papers by Prof. Moti Segev et al. unveil the first topological insulator laser



/19

H2Pro startup is established by Profs. Gideon Grader and Avner Rothschild to commercialize their innovative green hydrogen production technology



/20

A prototype liquid lens from Prof. Moran Bercovici's FLUTE project is assembled aboard the International Space Station



/23

Groundbreaking Two-Dimensional (2D) Materials Center opens with a dedicated Russell Berrie Foundation grant



/24

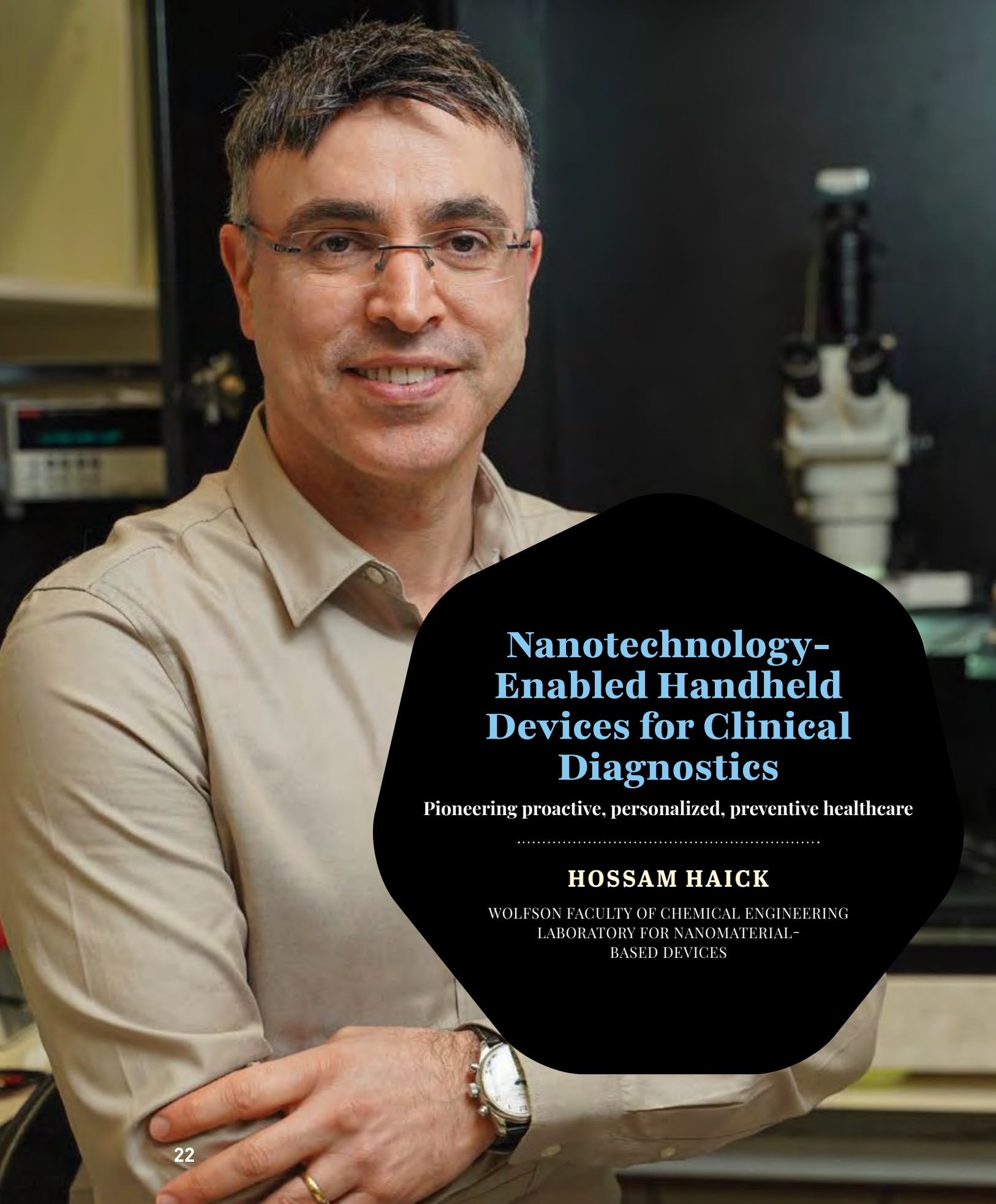
Julich-Aachen-Technion Umbrella Winter School series resumes after COVID-19





Nano Breakthroughs

& Research Highlights



Nanotechnology- Enabled Handheld Devices for Clinical Diagnostics

Pioneering proactive, personalized, preventive healthcare

HOSSAM HAICK

WOLFSON FACULTY OF CHEMICAL ENGINEERING
LABORATORY FOR NANOMATERIAL-
BASED DEVICES



This forward-thinking approach underscores RBNI’s role as a leader in technological innovation for healthcare, dedicated to improving healthcare by bringing clinical-level diagnostics into the fabric of everyday life. The pioneering work at Prof. Hossam Haick’s Laboratory for Nanomaterial-Based Devices (LNBD), envisions a future where healthcare is patient-centered, helping individuals to take charge of their own well-being.

At the heart of this vision are devices based on nanosensors, which can detect and analyze minute quantities of biological markers exhaled in breath or metabolic byproducts secreted in sweat. These nanosensors are crucial for measuring and monitoring human health at the molecular level without the need for invasive procedures such as blood draws or biopsies.

One of the LNBD team’s key accomplishments is the invention of an AI nanoarray for breath analysis. This portable 2 × 3 × 0.2 cm device can diagnose over 23 diseases from exhaled breath using a rapid, non-invasive, and inexpensive method (about US\$2 per test), making it accessible for developing countries. Its strength lies in a uniquely

balanced nanomaterial array that mimics the human olfactory system.

The LNBD nanotechnology-enabled breath testing devices have been evaluated in more than 40 hospitals worldwide, with impressive clinical results. The nanoarray-based breath test has been successfully implemented for various types of cancers, chronic and acute kidney disease, hepatic disease, pulmonary arterial hypertension, and other diseases. For many disease states, the device was able to discriminate between sub-categories of a specific disease, and between volatile organic compounds associated with genetic mutations. These aspects aid in diagnosis and personalized treatment.

These self-healable smart patches can equip computers, robots, and smart objects with the sense of touch.

Haick and team have also developed smart patches that mimic human skin, simultaneously sensing pressure, humidity, temperature, and chemical analytes. These self-healable smart patches can equip computers, robots, and smart objects with the sense of touch. The patented technology has high tactile resolution that exceeds human fingertip touch sensation. These features place this technology at the forefront of today’s tactile smart patch market, opening new technological and business opportunities, such as touch-sensitive robots and medical devices, prosthetic limbs with tactile feedback, and wearable smart patches for sports and rehabilitation.

The potential of smart patch technology for health monitoring spurred a collaboration between Haick, the

Gates Foundation, and the World Health Organization (WHO), to develop a low-cost (US\$1) wearable patch that detects infectious diseases for populations without access to medical infrastructure.

The LNBD groundbreaking smart wound-healing patch is a suture-less self-healing “band-aid” that not only closes wounds but also monitors healing and delivers treatment. The patch helps healthcare providers to make timely interventions based on changes in pH, temperature, and other key biomarkers. The patches are biocompatible reflecting LNBD’s commitment to developing sustainable healthcare technologies.

By combining nanosensors, molecular imaging, and AI, LNBD is pioneering a future where healthcare is proactive, personalized, and preventive. These technologies allow for continuous, non-invasive monitoring of health conditions, making it possible to anticipate and prevent serious diseases. The shift from reactive to proactive medical practices will profoundly impact healthcare, promising a future where diagnostic clinics are as accessible as the devices we carry every day.

Did You Know?

NANOTECHNOLOGY-ENABLED HAND-HELD DEVICES for clinical diagnostics aim to transform medical diagnostic testing, promising to revolutionize patient care by moving testing from specialized labs directly to the patient. Leveraging the unparalleled potential of nanosensors, healthcare will become more accessible, personalized, and efficient.





The dream of every scientist is to establish a new field of research and make discoveries that will impact the world of science. Topological Photonics is such a field, pioneered at Technion, by Distinguished Prof. Mordechai (Moti) Segev's group in 2013. Their groundbreaking paper, "Photonic Floquet Topological Insulator," published in *Nature*, has now been cited more than 3,500 times. Today, the field is actively pursued by hundreds of research groups worldwide. The ideas were conceptualized by Segev together with PhD student Yonatan Plotnik and postdoc Mikael Rechtsman, collaborating with Segev's former postdoc, Alex Szameit, then an assistant professor in Germany.

Photonic topological insulators are photonic systems on a chip (photonic circuits) which display flow of light that is immune to defects and disorder. Namely, the light flows in a given direction, and when it encounters a defect – the light simply circumvents it, without being scattered back or sideways. This phenomenon of "topologically protecting the flow of light" has many applications, especially in large-scale photonic circuits where fabrication defects and inhomogeneities are inevitable.

An important application is the protection of quantum light, termed "topological protection of entanglement". The idea was conceptualized by Segev's group in 2016. Together with Prof. Ben Eggleton's group at the University of Sydney, their joint postdoc Andrea Blanco-Redondo achieved the first proof-of-concept experiment, published in *Science* in 2018.

Perhaps the single most important application of topological photonics is the Topological Insulator Laser. This is an array of tiny semiconductor lasers

that lock together to act as a single, high-power, highly coherent laser. The topological insulator laser has the potential to solve a longstanding problem: scaling up the power emitted by semiconductor lasers, undoubtedly the most common lasers. They are tiny devices made on a chip that are very efficient in converting electric energy into coherent light, far beyond the efficiency of any other laser type. However, as known since the late 70s, the power emitted by a single semiconductor laser is severely limited.

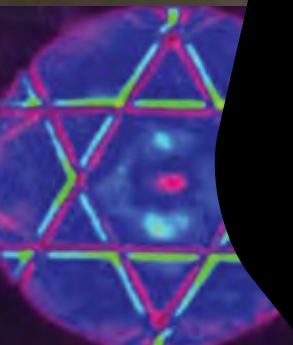
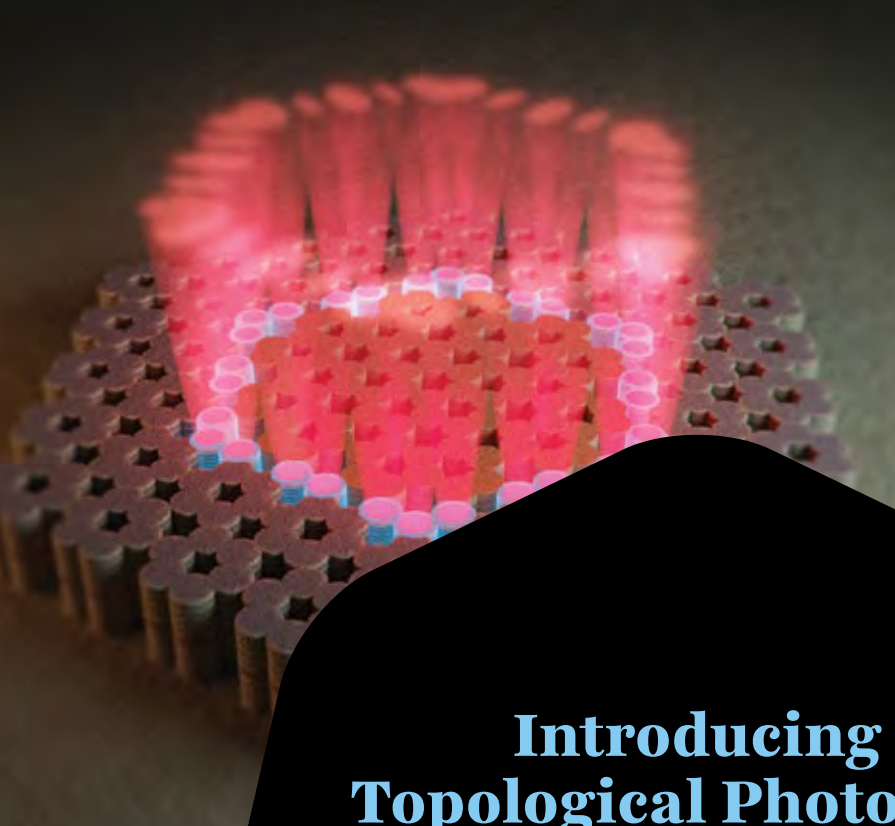
From the mid-80s to 90s, researchers attempted to make arrays of semiconductor lasers which are densely positioned on a single chip, aiming for the lasers to lock together and act as a single laser. These attempts largely failed.

The problem remained unsolved for decades, until Segev, along with his PhD student Gal Harari and postdoc Miguel Bandres came up with the idea to apply the principles of topological photonics to semiconductor lasers. After patenting the basic concept, the group collaborated with Profs. Demetri Christodoulides and Mercedeh Khajavikhan from CREOL at UCF. They implemented the first experimental demonstration of 40 lasers locked using the special properties of topologically protected light flow. The group published two back-to-back papers in *Science* in 2018: a conceptual theory paper and a paper presenting the experiments. These papers have been widely cited, and triggered follow up by groups worldwide. Segev's group expanded this discovery by demonstrating a topological array of Vertical Cavity Surface-Emitting Lasers (VCSEL) published in *Science* in 2021. The lead authors were Alex Dikopoltsev, then a PhD student in Segev's group, and Tristan Harder from the group of Profs.

Sebastian Klemmt and Sven Höfling at the University of Würzburg, Germany, in collaboration with the Technion team.

Over the years, there have been many more ideas proposed and demonstrated within the research field of Topological Photonics. It is still too early to say which ideas will find their way into commercial products, but it is already clear that topological photonics are here to stay, and this exciting field continues to evolve in new and unexpected ways.

Segev is the Robert J. Shillman Distinguished Professor of Physics and Electrical Engineering and Co-founder of the Helen Diller Quantum Center. He has received major international recognition, including the highest awards in laser physics, photonics, and quantum electronics: the 2007 Quantum Electronics Prize of the European Physical Society, the 2009 Max Born Award of the Optical Society of America (now Optica), and the 2014 Arthur Schawlow Prize of the American Physical Society. He is also the recipient of Israel's three most prestigious honors: the 2024 Rothschild Prize, the 2019 EMET Prize, and the 2014 Israel Prize in Physics. Segev is an International Member of both the U.S. National Academy of Sciences (NAS) and the American Academy of Arts and Sciences (AAAS). Beyond all his personal achievements, Segev takes pride in the accomplishments of his students and postdocs—among them are 26 professors across the USA, Germany, Taiwan, Croatia, Italy, India, China, and Israel, and many others in senior R&D positions in industry.



Introducing Topological Photonics: a new field of research

MORDECHAI SEGEV

FACULTY OF PHYSICS & VITERBI FACULTY OF
ELECTRICAL AND COMPUTER ENGINEERING
HEAD OF THE SOLID STATE INSTITUTE

*The dream of every
scientist is to establish
a new field of research,
and make discoveries
that will impact the
world of science.
Topological Photonics
is such a field.*

Prof. Moti Segev surrounded by his former graduate students—now faculty members and senior research scientists—who gathered to honor him upon receiving the EMET Prize in 2019.



The MEGA-plate: An Oracle of Antibiotic Resistance

Machine learning assists personalized antibiotics
using infection history and genomic data

ROY KISHONY

FACULTY OF BIOLOGY



Prof. Roy Kishony's research group addresses critical questions in understanding the origins of infecting bacteria, the diversity of pathogenicity within colonizing bacterial populations, their evolution during infection and across recurrent infections. By focusing on scenarios where bacterial isolates from different body sites and multiple time points can be obtained, the team can assess evolutionary dynamics in real-time. Landmark research projects, published by the Kishony team in leading journals, are summarized below.

Visualizing evolution of microbial antibiotic resistance (2016)

Kishony's team invented the Microbial Evolution and Growth Arena (MEGA) plate as a visual tool to study how bacteria evolve resistance to antibiotics over space and time. It is a massive (120 x 60 cm) petri dish with increasing gradients of antibiotics

across zones. As bacteria grow and evolve, they can be seen adapting and moving into regions with higher antibiotic concentrations, offering real-time observation of evolutionary dynamics. The plate has become widely recognized for its elegant demonstration of Darwinian evolution. The MEGA plate's time-lapse movies have over 30 million views, and have been presented at major scientific forums, including the United Nations.

The MEGA plate visually tracks the evolution of antibiotic resistance, revealing key phenomena such as hyper-mutation, compensatory adaptation, and clonal interference. By sequencing over 250 clones, the group identified multi-step evolutionary pathways and novel resistance genes. This system highlights the dangers of low-level antibiotic exposure and offers a unique tool for studying microbial evolution.

Rapid methicillin resistance diversification (2021)

Focusing on early colonization in neonates, the Kishony group investigated how an opportunistic pathogen evolves and spreads. In collaboration with Rambam Hospital, they isolated *Staphylococcus epidermidis* in samples taken from preterm neonates, including multiple clones from numerous body sites for each time point. Using whole-genome sequencing, they found high genetic variability at the strain level, indicating that each neonate is colonized by multiple coexisting strains. However, within a strain, there was minimal single nucleotide polymorphism (SNP) variability. They then developed a computational pipeline to score gene content in each clone by aligning sequences to a common pan-genome. This analysis revealed rapid gene diversification, specifically around the methicillin resistance locus. Using nanopore long-read sequencing to map these genomic sites,



Did You Know?

OUR BODIES ARE TEEMING WITH BACTERIA.

They are prevalent on the skin and along the digestive tract. Most of these bacteria are benign, and some are even beneficial to our health. However, when these bacteria traverse our body's protective layer, they may cause an infection. Moreover, once exposed to our immune system and frequently to antibiotic drugs, these bacteria often evolve and become resilient. Understanding how bacteria switch from colonization to infection and how they continue to evolve during infection, provide valuable insights on informing preventive clinical practices and treatment strategies.

they discovered that these genetic variations are driven by multiple homologous recombination sites, creating a functional combinatorial genomic diversity within each strain.

Fight against COVID (2021)

The group contributed to understanding COVID-19 vaccine effectiveness at personal and community levels. These studies were cited as a basis for key public policy decisions, including those of Dr. Walensky, then-Director of the USA Centers for Disease Control and Prevention, and Dr. Anthony Fauci, then-Chief Medical Advisor to the President.

Antibiotic resistance in UTIs (2022)

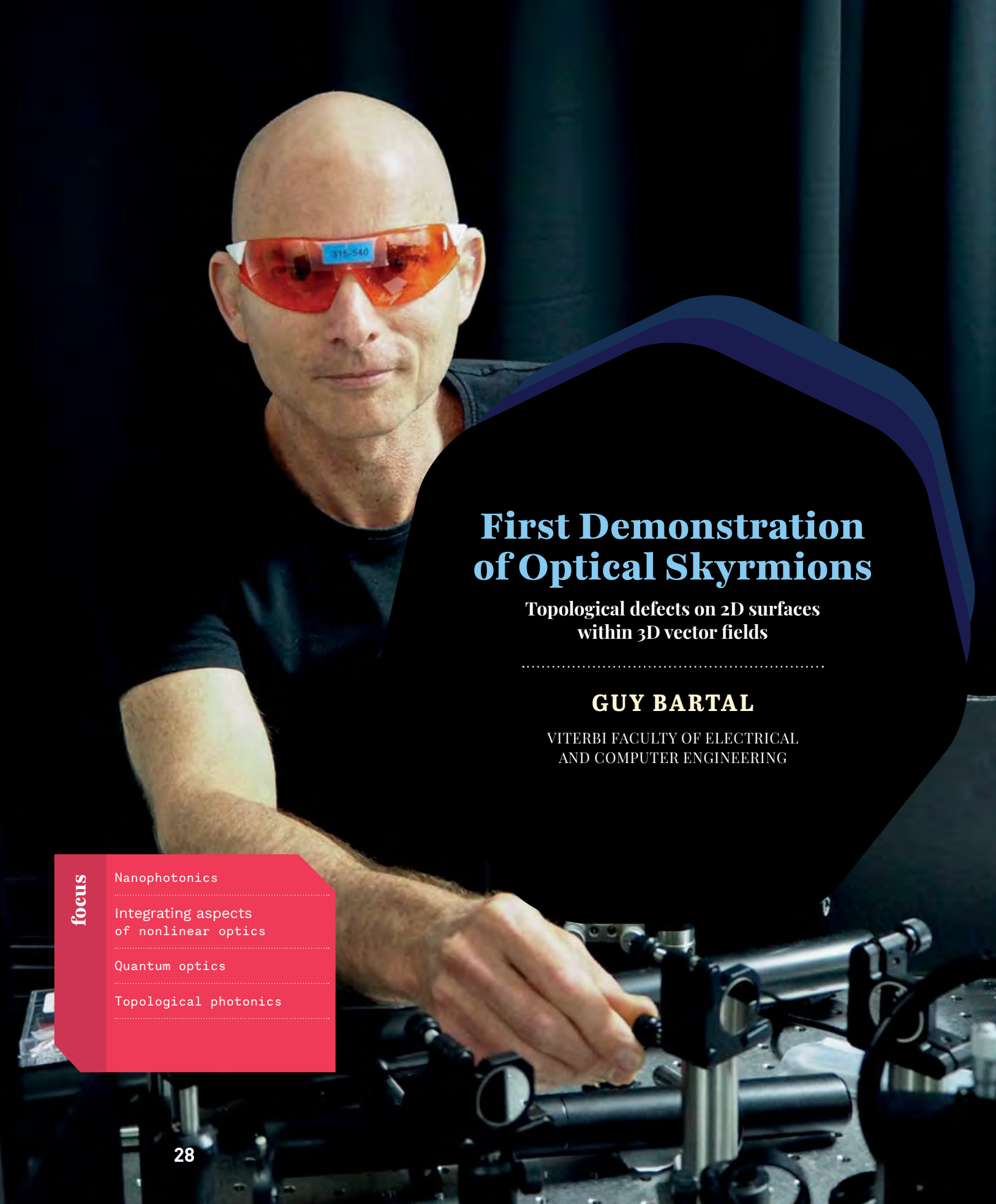
This study combines analysis of electronic health records of urinary tract infections (UTI) with whole-genome sequencing of bacterial isolates collected from patients before and after failed antibiotic treatments. The researchers found that treatment failure

due to antibiotic resistance is highly common, yet not driven by de novo mutations, rather by complete replacement of the original strain with a new, treatment-resistant strain. These new strains could be predicted as they often matched past infections recorded for the patient. This enabled the team to devise a machine-learning prescription algorithm that can suggest personalized antibiotic treatments to minimize treatment failure and gain resistance.

Antibiotic combinations (2022)

This study explores how antibiotic combinations affect the long-term clearance of *Staphylococcus aureus*. Using high-throughput microplating and image analysis, the researchers found that drug combinations often result in reciprocal suppression, where antibiotic mixtures were less effective than individual drugs. Increasing the number of antibiotics typically reduced clearance efficacy, except for specific drugs

targeting non-growing persister cells. Remarkably, suppressive combinations counteracted resistance, including methicillin-resistant *S. aureus* (MRSA). These findings highlight the importance of systematically evaluating drug combinations to design more effective, resistance-proof treatments.



First Demonstration of Optical Skyrmions

Topological defects on 2D surfaces
within 3D vector fields

GUY BARTAL

VITERBI FACULTY OF ELECTRICAL
AND COMPUTER ENGINEERING

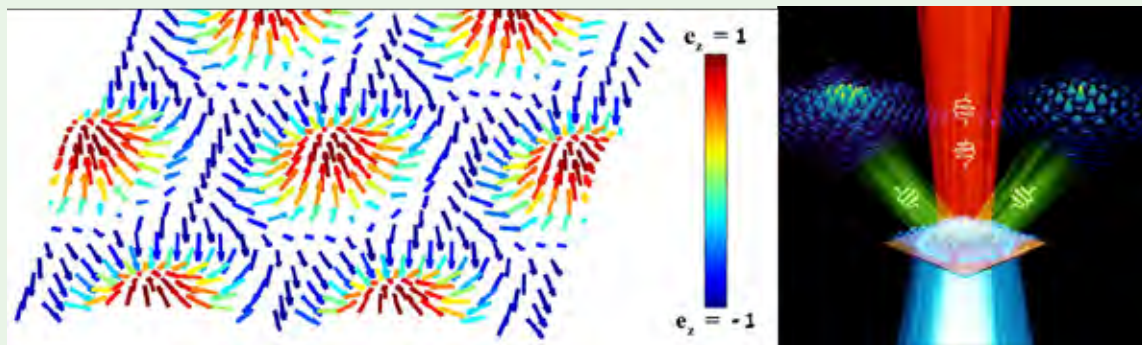
focus

Nanophotonics

Integrating aspects
of nonlinear optics

Quantum optics

Topological photonics



Left: First observation of optical skyrmions – the texture of light (spatially varying direction of the electric field) was mapped by near-field microscopy, showing a texture similar to well-known skyrmions in magnetic materials. *Right:* a new approach to map the evanescent field of surface and guided modes, harnessing optical nonlinearity of the host material



Prof. Guy Bartal's team made a significant breakthrough by introducing the concept of "light textures," referring to specific arrangements and distributions of light that exhibit unique properties. They were the first to demonstrate optical skyrmions - topological defects found within three-dimensional vector fields, and bound to two-dimensional surfaces. This discovery was facilitated by the evanescent nature of surface-plasmon polaritons – surface waves generated by coupling electromagnetic fields to electron oscillations in metal. The evanescent nature of these waves enables the formation of such topological structures. This work was published in *Science* and has inspired hundreds of follow-up studies.

The research team also focuses on developing new tools and approaches for imaging nanophotonic fields, that cannot be observed in conventional microscopes owing to their small feature-size – smaller than the wavelength of the light that carries them. In addition to developing a unique approach for

well-established scanning near-field microscopy, the Bartal team has pioneered a completely new approach that enables imaging of surfaces and guided waves without scanning. This approach leverages the optical nonlinearity that is present in any nanophotonic platform – metal, high-index dielectric, or even a single interface – and provides real-time

The team pioneered a completely new approach enabling imaging of surfaces and guided waves without scanning

subwavelength imaging with unprecedented information about the properties of the nanophotonic fields.

This pioneering approach transforms our understanding of how light behaves in complex environments, including photonic integrated circuits. Recently, the group has focused on the emerging fields of quantum optics and quantum information, generating new quantum states based on the two pillars of nanophotonics and nonlinear optics.

Did You Know?

NANOPHOTONICS examines the interaction between light (photons) and nanoscale materials and structures, employing principles from both classical and quantum mechanics. It involves manipulating light at the nanometer scale to create new optical devices and technologies. In nonlinear optics, the optical properties of materials change in response to light intensity, leading to phenomena such as mixing between frequencies and the generation of photons with new attributes.

QUANTUM OPTICS investigates the quantum nature of light, both as it travels in free-space and when interacting with matter. It explores phenomena such as photon entanglement and quantum superposition, which are fundamental for developing quantum computing and cryptography technologies.

TOPOLOGICAL PHOTONICS is a newer subfield that merges concepts from topology—a branch of mathematics concerning the properties of space preserved under continuous transformations—with photonics. It studies how light can be guided and controlled using topologically protected states, and seeks new forms of electromagnetic fields inspired by topological concepts.



Putting the Spin on Quantum Nanocrystals

Optical and magneto-optical properties of low-dimensional semiconductors for next-generation quantum and spin-based technologies

EFRAT LIFSHITZ

SCHULICH FACULTY OF CHEMISTRY

Prof. Efrat Lifshitz's group is at the forefront of research in the development and magneto optical characterization of low-dimensional semiconductor nanocrystals.

(l-r) Idan Cohen, Kusha Sharma, Jiban Mondal, Prof. Efrat Lifshitz, Reut Eshkor, Tamar Avitsuk, and Ellenor Geraffy



Prof. Efrat Lifshitz's group is at the forefront of research in the development and magneto optical characterization of low-dimensional semiconductor nanocrystals. This approach combines material development with extensive experimental and theoretical studies of optical and magneto-optical properties.

Over a period of 35 years, the group's research has evolved from investigating van der Waals (vdWs) bulk crystals and their intercalation compounds to making significant contributions to the study of colloidal II-VI and IV-VI semiconductors and, more recently, exploring perovskites and magnetic vdWs structures. A recurring theme is gaining a deep understanding of how surfaces, interfaces, trapping/doping, and spin-related effects impact the photophysics of these materials. Advanced magneto-optical techniques have been used to reveal new physical phenomena, such as optically detected magnetic resonance (ODMR), magneto-micro-photoluminescence (M- μ PL), and microwave-modulated PL. These include the suppression of Auger quenching, the Rashba effect, anisotropies, and magnetic-electronic coupling—addressing critical scientific questions relevant to emerging optoelectronic and spin-based devices.

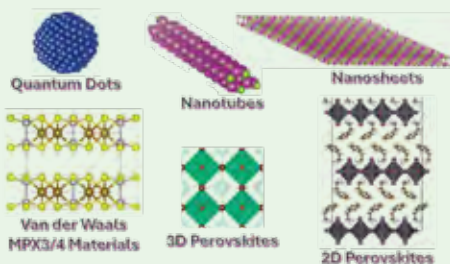
Colloidal Nanostructures: The group developed various core/shell colloidal quantum dots, rods, and platelets from II-VI and IV-VI semiconductor materials, with optical tunability across the visible and near-infrared spectra. ODMR measurements revealed that carriers were trapped at defect sites along the core/shell interface, underscoring the need for a close match in crystallographic and dielectric properties. They pioneered the introduction of alloyed compositions at these interfaces to address this matching issue, reducing many-body Coulomb interactions (Auger quenching) and eliminating fluorescence intermittency. This innovation resulted in stable, blinking-free fluorescence under continuous-wave excitation, making these structures suitable for use in light sources or photovoltaic cells.

Magnetically Doped Colloidal Nanostructures: The Lifshitz group utilized spectrally stable core/alloyed-shell colloidal nanostructures to create diluted magnetic semiconductors on the nanoscale, doped with first-row transition metal cations. ODMR studies demonstrated the impact of these dopants on recombination effects, providing direct evidence of spin-exchange interactions between dopant spins and host carrier spins, which is significant for quantum technologies.

3D and 2D Perovskite Materials: Semiconductor halide perovskites (HPs) feature an inorganic network with organic moieties filling the voids, leading to significant changes in their physical properties. The group conducted comprehensive M- μ PL studies on single HP nano-cubes (3D) and platelets (2D), revealing several key phenomena: (i) The softening properties led to

symmetry-breaking inversion and the development of the Rashba effect, inducing circularly polarized optical transitions with relatively long spin coherence times, useful for quantum technologies; (ii) Further studies highlighted the influence of nuclear spins via hyperfine interactions (Overhauser effect) on spin-coherence time, with practical implications; (iii) Detailed studies of 2D HP single crystals uncovered that the soft configurations do not possess random structures but feature two chiral enantiomers of the inorganic skeletons.

Magnetic Lamellar Materials: The group's early pioneering work on vdWs materials focused on intercalation processes and their impact on the physical properties of lamellar materials. This research predated the current surge in interest driven by the discovery of graphene. While much of the global focus has been on the electrical and optical properties of lamellar materials, the group dived into exploring magnetic vdWs compounds with a general formula MPX_3 (M = 1st-row transition metals, X = chalcogenides) in both bulk and single-layer forms. These compounds exhibit ferro- and anti-ferromagnetic behaviors combined with semiconducting properties. The key research questions involve the correlation between magnetism and optical transitions. Their two recent projects revealed exceptionally sharp optical transitions with linear polarization along the direction of magnetization, which can be tuned by composition or external stimuli. Some of these materials have been used in prototype devices such as lamellar-based photodetectors and X-ray sources.



Nano-Ghosts

A universal platform for targeted drug
and gene therapies

MARCELLE MACHLUF

FACULTY OF BIOTECHNOLOGY AND FOOD ENGINEERING
CANCER DRUG DELIVERY AND
CELL-BASED TECHNOLOGIES LAB





Nano-Ghosts (NGs) – a targeted therapeutic platform of nano-sized drug delivery vehicles for treating malignant and inflammatory diseases was invented by Prof. Marcelle Machluf. This platform harnesses the ability of mesenchymal stem cells (MSCs) to target diseased tissues and tumors, and interact with resident cells, while carrying diverse therapeutic agents and engineered surface functions.

Over the past decade, the Machluf group has developed the proprietary Nano-Ghost technology, which involves the production of inanimate, yet bioactive nanovesicles derived from the cytoplasmic membranes of MSCs. The scalable,

cGMP-compliant process begins with the removal of the cytoplasm and organelles from MSCs to obtain inanimate ghost cells that retain the MSC membrane. These ghost cells are then downsized to produce nano-vesicles termed Nano-Ghosts (Figure 1).

The NG technology was designed to facilitate the implementation of MSC capabilities such as targeting and immunomodulation in an inanimate delivery platform for treating malignant and inflammatory diseases. This method introduces the MSC membrane repertoire, while overcoming MSC susceptibility to host-induced changes and their poor retention at the injection site.

The accumulated research has revealed that NGs recapitulate the homing capabilities of MSCs to tumors with the following models: orthotopic xenograft lung cancer metastatic model,

xenograft and allograft prostate tumor models, and orthotopic and heterotopic pancreas tumor and melanoma models. In immunocompetent animals, the NGs were shown to target tumor-infiltrating immune cells in addition to cancer and endothelial cells. Furthermore, the NGs' homing capabilities toward sites of inflammation were demonstrated in an osteoarthritis model. Facing physiological barriers, the NGs were shown to bypass the blood-brain barrier and target brain tumors as well as neuroinflammation. Indirect evidence supporting the benefits of the NGs' inanimate state was provided by safety studies showing that repeated administrations of xenogeneic NGs did not cause a secondary immune response, which contrasts with the immunization detected following repeated transfusions of allogeneic MSCs.

It was further established that NGs can be loaded with a variety of bioactive compounds, including proteins (cytokines), nucleic acids (pDNA), siRNA, and peptides, whose targets were found inside or on the surface of the targeted cells. This led to dramatic therapeutic outcomes in diverse preclinical models. When systemically administered, these loaded NGs led to almost complete tumor inhibition in mice bearing human prostate cancer, and over 50% inhibition of established lung cancer metastases.

Based on this technology, the startup company NanoGhost was established.

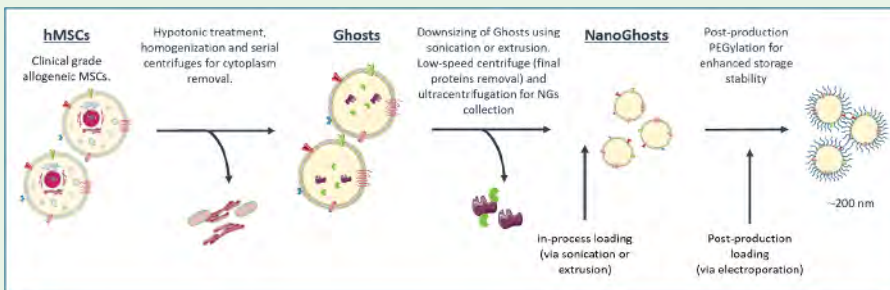
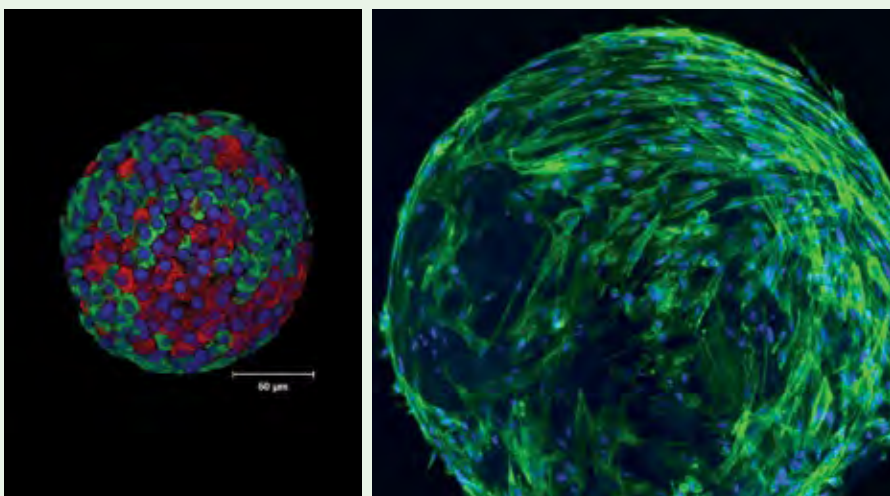
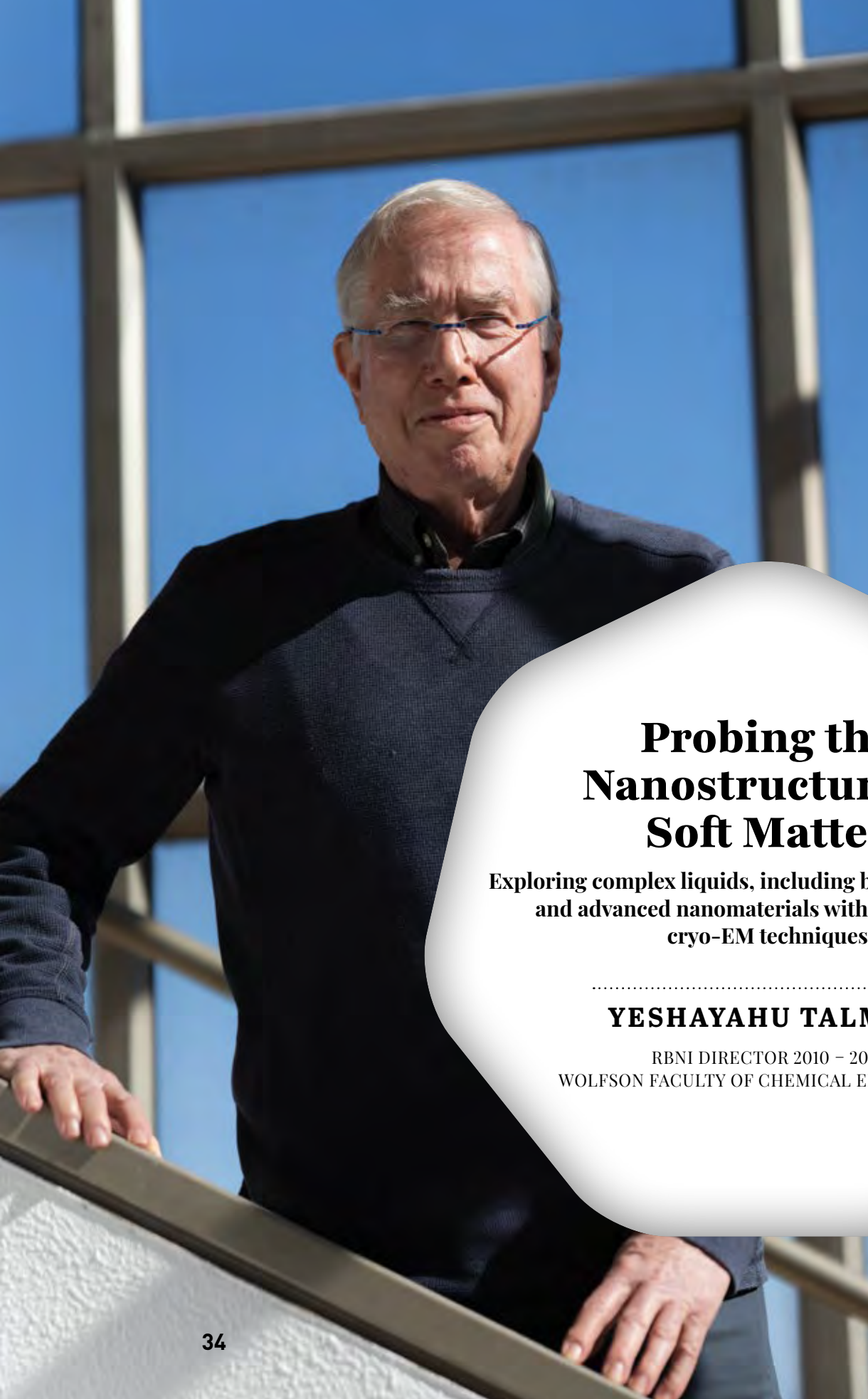


Figure 1: NG production process



(l-r) Pancreatic islet in a ppECM microcapsule, secreting insulin (red) and glucagon (green) while shielded from immune attack; Bovine mesenchymal stem cells cultured on plant-based microcarriers. The food-grade protein scaffolds support large-scale cell growth for sustainable cultured meat production. Live cells shown in green.



Probing the Nanostructure of Soft Matter

**Exploring complex liquids, including biological systems,
and advanced nanomaterials with cutting-edge
cryo-EM techniques**

YESHAYAHU TALMON

RBNI DIRECTOR 2010 - 2012
WOLFSON FACULTY OF CHEMICAL ENGINEERING



Prof. Yeshayahu (Ishi) Talmon's research group has worked on a class of materials known as soft matter, complex liquids or nanostructured liquids. These liquids consist of domains or aggregates, which range from a few nanometers to a few hundred nanometers in size. Such systems are widely found in biology (e.g., cell membranes), detergents (e.g. -surfactant micelles), and technology (e.g., microemulsions for enhanced oil recovery).

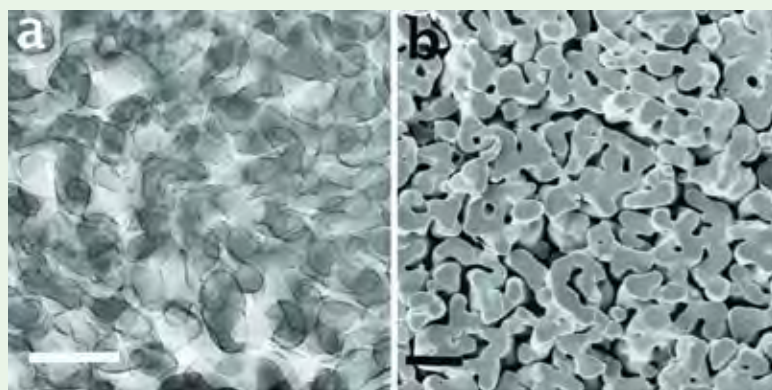
The support provided by RBNI through its graduate program and central research facilities has allowed his research group to study a wide range of complex liquids using state-of-the-art cryogenic-temperature transmission and scanning electron microscopy (cryo-TEM and cryo-SEM). This research has provided answers to some important open questions in colloid science. Notably, they mapped the evolution of a microemulsion from water-continuous to bicontinuous, to an oil-continuous single-phase. They also characterized a number of systems for genetic material delivery in gene therapy, and conducted in-depth studies on the complexation of polyelectrolytes with oppositely-charged molecules.

Recent projects have included the characterization of blood cells in both normal and pathological states, as well as the study of extracellular vesicles (EVs)—vesicle-like aggregates in the blood that play roles in cellular communication, disease, and pregnancy. The group's work has also extended to non-aqueous systems, including liquid

crystalline phases of carbon nanotubes (CNTs) and boron nitride nanotubes (BNNTs) in chlorosulfonic acid, which are critical for the development of advanced materials.

Throughout their work, they have advanced cryo-TEM and cryo-SEM methodologies, and the understanding of electron-beam interactions with specimens.

Figure 1 shows cryo-TEM and cryo-SEM micrographs of a microemulsion system, demonstrating the integration of both cryo-EM methodologies to study the nanostructure of soft-matter systems, which are highly sensitive to slight variations in composition and temperature.

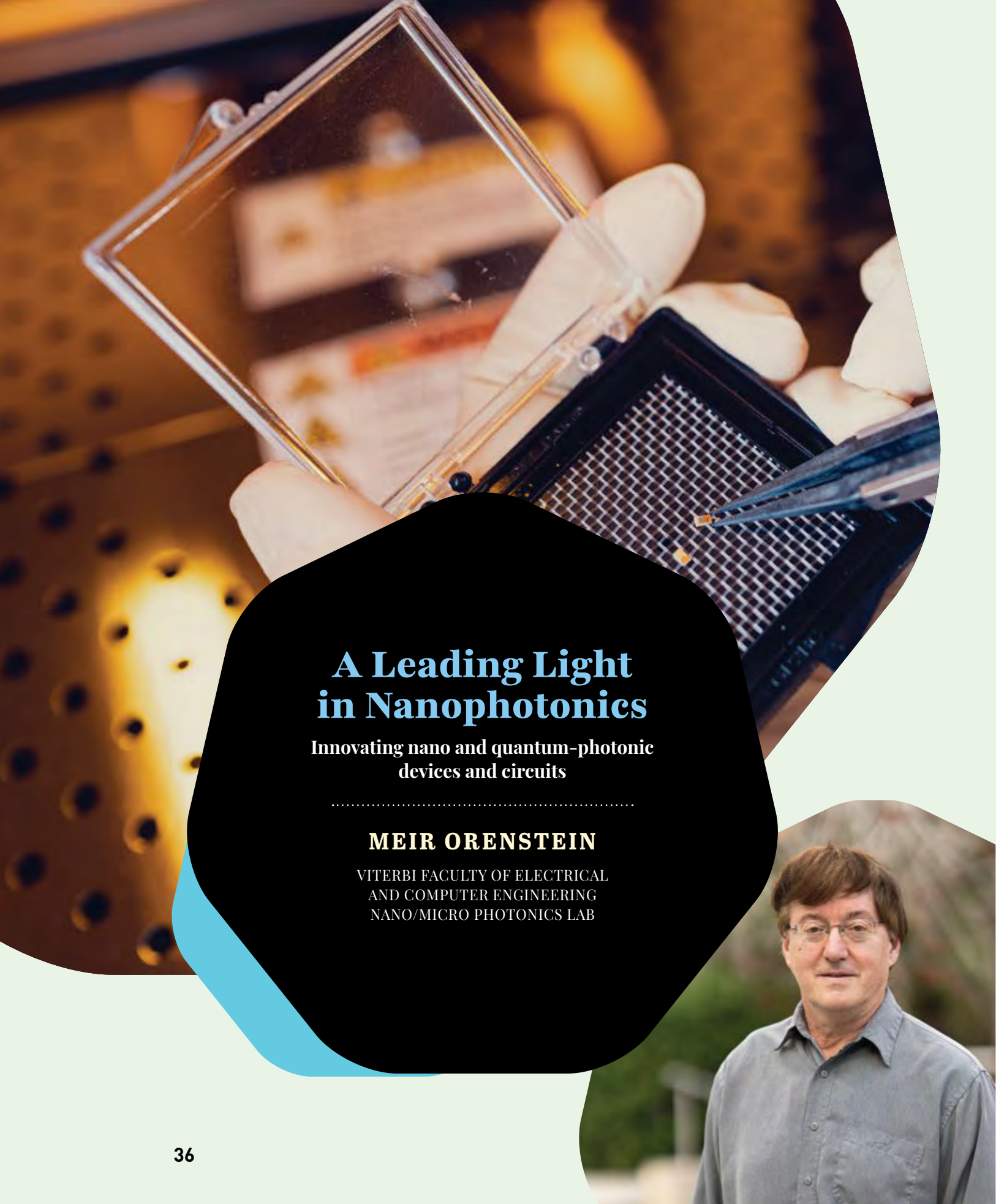


Cryo-EM of a bicontinuous microemulsion composed of water, isooctane and 7% of the nonionic surfactant C12E5 [pentaethylene glycol mono n-dodecyl ether] at 34 °C, with 40 wt.% oil in the water-oil mixture [a]: a. Cryo-TEM; b. Cryo-SEM. Scale bars correspond to 200 nm [a] and 500 nm [b].

Did You Know?

RBNI was the first institute of its kind in Israel, setting a precedent for other Israeli research universities with strong programs in the natural science and engineering, under the Israel National Nanotechnology Initiative (INNI). RBNI was also the first to establish a graduate studies program, which has graduated a significant number of outstanding MSc and doctoral students over the years. Talmon's group has included 20 of these students.

A key aspect of RBNI has been the development and maintenance of world-class infrastructure on the Technion campus. This involved acquiring sophisticated and costly equipment for use by multiple research groups in academia and industry, recruiting highly qualified personnel to operate the equipment, help design and run experiments, and train students and postdocs. RBNI also provided partial funding to support access to these core facilities.

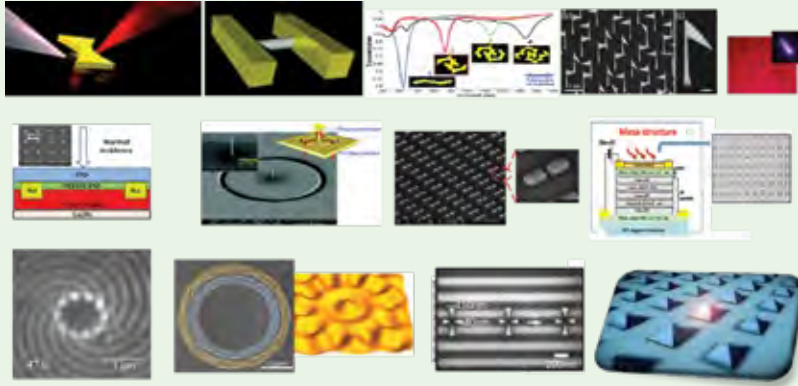


A Leading Light in Nanophotonics

**Innovating nano and quantum-photonic
devices and circuits**

MEIR ORENSTEIN

VITERBI FACULTY OF ELECTRICAL
AND COMPUTER ENGINEERING
NANO/MICRO PHOTONICS LAB



Research highlights

1st row: antenna designs (left to right) concave, coupled, "popcorn" designs, epitaxial InP nanoflag and light emission (purple)

2nd row: applications of nanoantennas (left to right) in solar cell, nano needle for concentration, array for enhancement of LEDs, array for enhancing quantum cascade detector.

3rd row: angular momentum and quantum (left to right): photo of nano light rotating, Spiral meta nano antenna and the nano field generated, nanoantennas on superconductor-wire photon detector, array of Si color centers on diamond – as photon source array.



Prof. Meir Orenstein's two main contributions are in nanophotonics and quantum-inspired nanophotonic devices and circuits.

Nanophotonics

Orenstein's group was among the pioneers in the emerging field, known as *nanoplasmonics*, where electrons in metals behave like a plasma. The reduced size not only saves real estate, but the concentration of light into a small dimension enhances useful interactions such as modulation, nonlinearity, and rate of light emission. The group proposed, fabricated and measured novel nano structured waveguides, that strongly impacted plasmon gap waveguides and transmission lines.

Orenstein's group shifted its focus to photonic behavior near nano metallic particles, known as nanoantennas, which have a major impact on the characteristics of light. They conducted extensive studies to enhance the design and application of actual photonic devices. They developed novel accurate designs and succeeded in fabricating nanoantennas with specific characteristics.

Nanoantennas were embedded in organic-inorganic solar cells to enhance their efficiency. In a pioneering paper, the team demonstrated that nanoantennas can dramatically increase the

In a pioneering paper, the team demonstrated that nanoantennas can dramatically increase the light emission rate from LEDs in the GHz regime, which is critical for photonic communication at the chip level.

light emission rate from LEDs in the GHz regime, which is critical for photonic communication at the chip level. They also integrated a nanoantenna structure in advanced quantum cascade detectors to improve light detection efficiency.

Their next challenge was to grow nanoantennas with a desired structure. The team grew nano flag structures and measured their enhanced characteristics. Their research achievements led to the establishment of a national Nanophotonics research program, with Orenstein as its director.

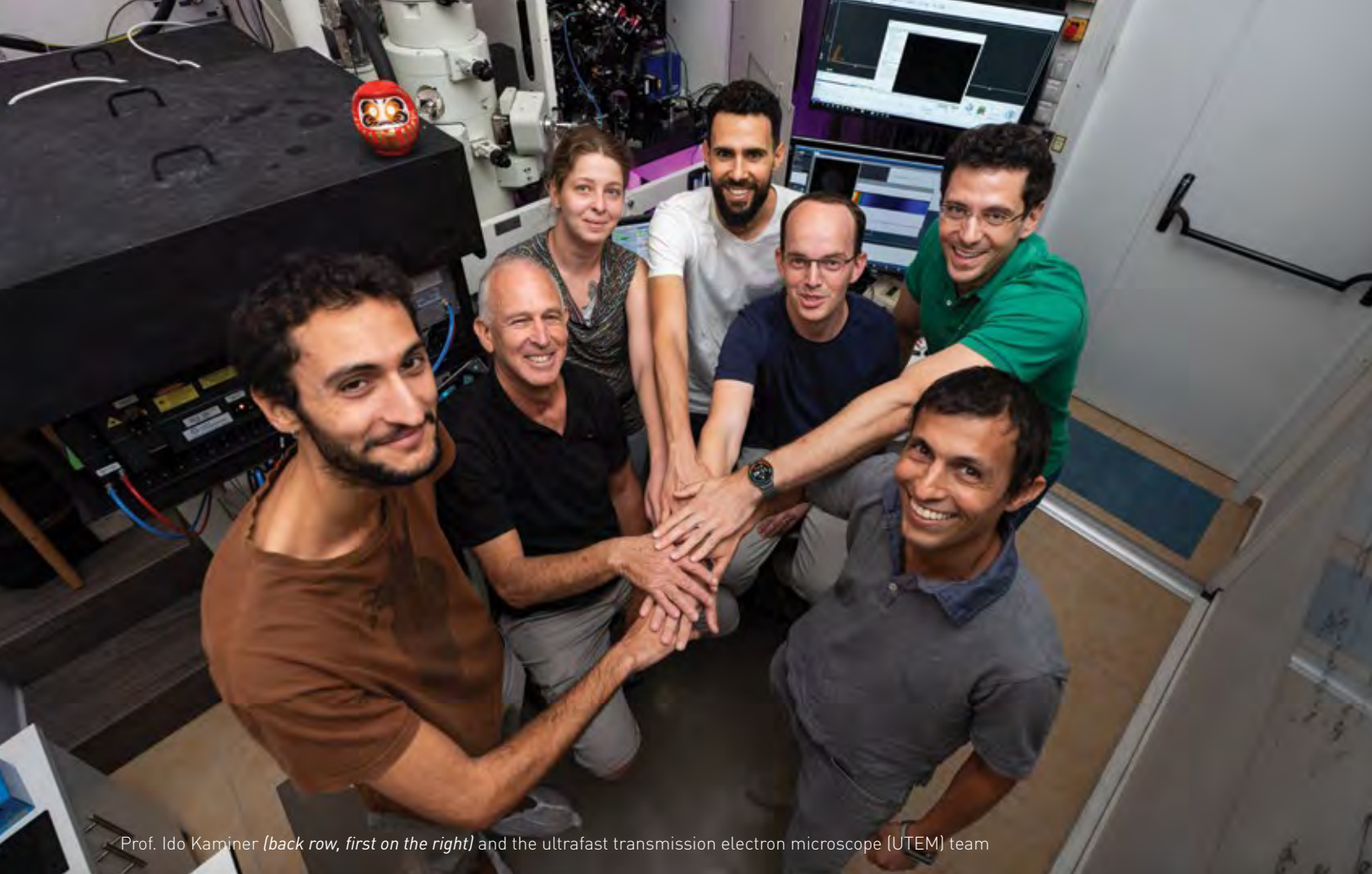
The team then applied nanoplasmonic activity to nano structures in order to generate nanoplasmons with angular momentum. This light rotation was measured for the first time using a combination of electron microscopy and ultrafast optical pulses which resulted in a motion video with a spatial resolution of a few nanometers and a temporal resolution of 100 atto seconds.

Quantum Nanophotonics

The Orenstein team investigated the use of nanophotonic structures as sources, quantum state manipulators, and detectors—

functions enabled or enhanced by their nanophotonic structures.

They integrated nanoantenna structures into a superconducting single-photon detector, achieving the broadest bandwidth performance for such devices. Building on this, they turned to photon emitters and achieved a breakthrough in the design and measurement of an emitter capable of producing photon pairs from a semiconductor quantum structure. Since this second-order process is inherently weak, they incorporated a nanoplasmonic structure, which enhanced the emission rate by several orders of magnitude. They also developed single-photon emitter arrays based on nitrogen-vacancy and silicon-vacancy in diamond. They demonstrated that the emission rate could be controlled and significantly enhanced by integrating nanoplasmonic antennas and specialized nanostructured CVD growth techniques.



Prof. Ido Kaminer (*back row, first on the right*) and the ultrafast transmission electron microscope (UTEM) team



Prof. Ido Kaminer (*bottom row, third from the right*) and the AdQuanta team

Pushing the Boundaries of Quantum Light

Exploring light–matter interactions to create new technologies and faster imaging tools

IDO KAMINER

VITERBI FACULTY OF ELECTRICAL
AND COMPUTER ENGINEERING
ADQUANTA LAB



Head of the AdQuanta Lab, Prof. Ido Kaminer has made significant contributions to the nano field, particularly at the intersection of quantum optics and photonics. He has pioneered new theoretical and experimental methods that explore quantum phenomena in traditionally classical conditions. His research group focuses on investigating the implications of quantum optics in attosecond science and free-electron physics, areas that have profound implications for the understanding of fundamental physics.

Among the lab's notable achievements is work on the radiation of relativistic charged particles and the interaction of light and matter under intense fields. This research is not only theoretical; it translates into practical applications that push the boundaries of nanotechnology and photonics.

Kaminer's lab employs advanced femtosecond lasers in transmission electron microscopes, achieving record spatial and temporal resolution that enables novel experiments in light–matter interactions. These experiments focus on nanophotonics and 2D materials,

exploring how engineered wavefunctions of matter and photons can lead to new, physical phenomena that are not encountered in natural settings. This line of inquiry is particularly important as it paves the way for disruptive applications, including novel light sources, such as tunable X-ray sources for spectroscopy and ultrafast detectors like scintillators for medical imaging.

Kaminer's group also works on developing new theory in quantum optics and many-body quantum optics. They established the foundations of macroscopic quantum electrodynamics (MQED) for photonic quasiparticles, enabling non-vertical electronic transitions in quantum well and semiconductor devices, creating a new kind of tunability. Kaminer's group created a paradigm shift in the understanding of free-electron radiation, connecting it to the field of quantum optics. They performed the first experiment on free-electron interaction with quantum light, demonstrating that the quantum statistics

of photons can be imprinted on the electron.

Kaminer's group created a paradigm shift in the understanding of free-electron radiation, connecting it to the field of quantum optics.

Kaminer has won numerous awards and grants, including ERC Starting and Consolidator Grants, the Krill Prize, the 2022 Schmidt Science Polymath Award, the 2021 Blavatnik Award in Physical Sciences and Engineering in Israel, the 2022 Adolph Lomb Medal (the leading international award for a young scientist in optics, under 35), and the 2024 ACS Photonics Young Investigator Award. Kaminer was elected to the Israel Young Academy, dedicated to addressing critical national and international issues by advancing young researchers and scientists from across diverse academic disciplines.



Levenberg's work exemplifies the power of interdisciplinary research in driving scientific and technological innovation, spanning from fundamental research to practical applications.

Tissue Engineering Pioneer

Generating single-cell technologies, regenerative medicine platforms, and rapid antibiotic tests

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SHULAMIT LEVENBERG

FACULTY OF BIOMEDICAL ENGINEERING
STEM CELL AND TISSUE ENGINEERING LAB

Prof. Shulamit Levenberg is world-renowned for her groundbreaking research and innovations in tissue engineering, stem cell research, and nanotechnology. As a member of RBNI, Levenberg has developed cutting-edge technologies bridging engineering and life sciences.

One of Prof. Levenberg's notable achievements is her work in microfluidics, particularly the development of a novel nanoliter droplet microarray. This innovative platform enables prolonged culture of single adherent and non-adherent cells, allowing for unprecedented tracking of single cell metabolism and dynamics. The nanoliter droplet microarray enhances single cell metabolism tracking by providing an isolated microenvironment for each cell, eliminating cross-contamination. It allows for prolonged culture of both adherent and non-adherent single cells and enables real-time monitoring of cell metabolism and dynamics over

The nanoliter scale facilitates efficient delivery of stimuli and assay reagents to individual cells while maintaining appropriate gas exchange for cell viability. The system allows for time-dependent monitoring of cell surface markers. Its high-throughput format enables parallel analysis of many single cells, and it allows for non-invasive metabolic profiling. The platform's versatility makes it suitable for studying various cell types and cellular processes.

Nanosynex, a company developing rapid antibiotic susceptibility tests, is based on technology invented at Levenberg's lab. The product addresses the critical need for quick and accurate determination of antibiotic resistance.

Levenberg has also developed micro-bioreactors designed to support stem cell growth and manipulation. These serve as novel biotechnology platforms for biomedical device and tissue engineering applications.

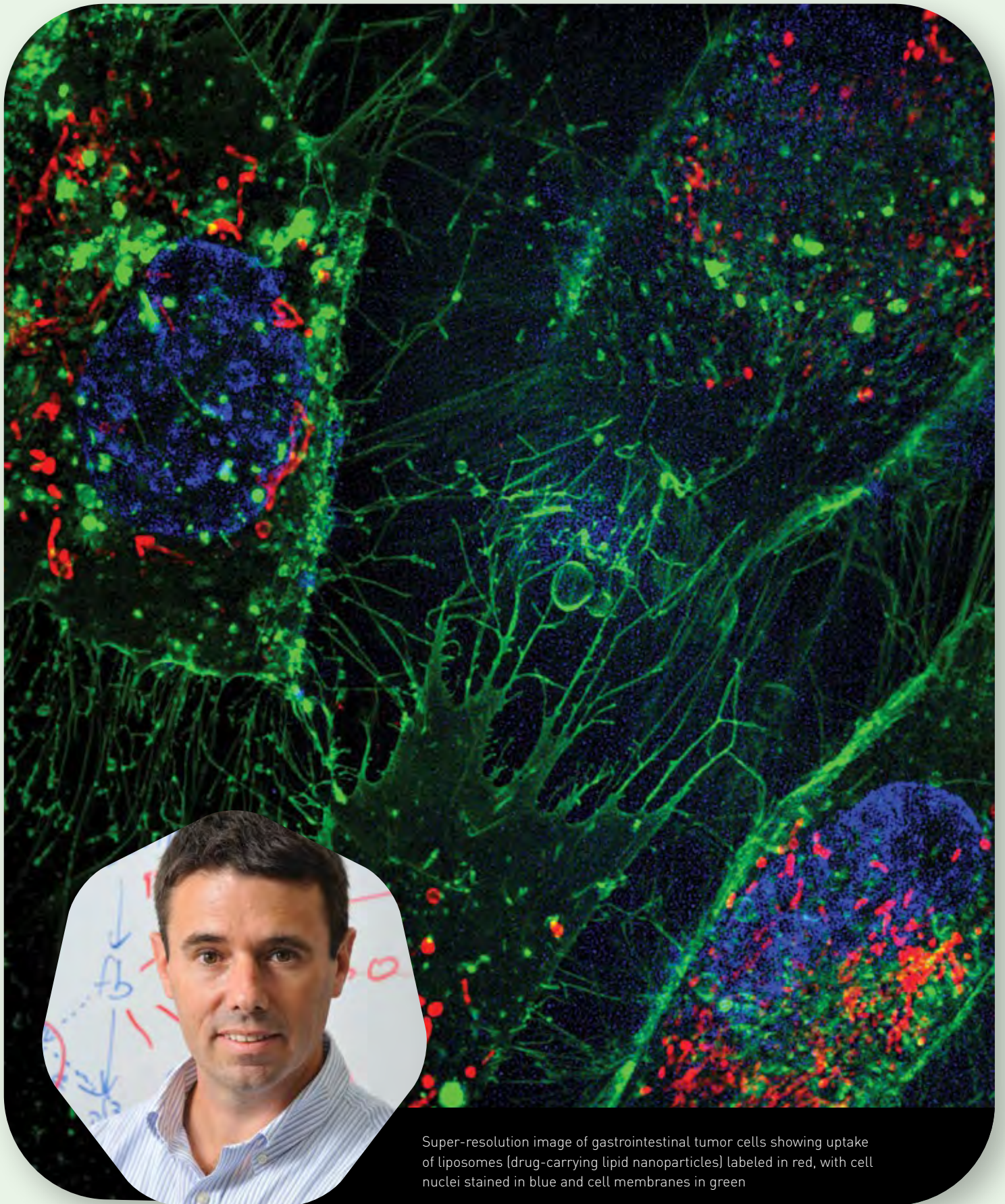
In regenerative medicine, she has made significant strides using exosomes for spinal cord regeneration, modifying them with pRTEN siRNA to

extended periods.

enhance their regenerative potential. This work led to the co-founding of Nurexone, a company developing exosome-based treatments for central nervous system indications, focusing on acute spinal cord injuries. This venture represents a significant step towards translating her research into clinical applications, potentially offering new hope for patients with spinal cord injuries.

Levenberg's work exemplifies the power of interdisciplinary research in driving scientific and technological innovation, spanning from fundamental research to practical applications. Her ongoing research and leadership continue to push the boundaries of integrating nanotechnology with tissue engineering and regenerative medicine, promising further innovations that could transform medical treatments and improve patient outcomes.

Prof. Shulamit Levenberg holds the Stanley and Sylvia Shirvan Chair in Cancer and Life Sciences and is former dean of the Faculty of Biomedical Engineering. She directs the Technion Center for 3D Bioprinting.



Super-resolution image of gastrointestinal tumor cells showing uptake of liposomes (drug-carrying lipid nanoparticles) labeled in red, with cell nuclei stained in blue and cell membranes in green

Agile Nanotechnology for Precision Medicine

Nanoparticles for targeted therapy with built-in diagnostics and smart drug release

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AVI SCHROEDER

WOLFSON FACULTY OF CHEMICAL ENGINEERING
LOUIS LABORATORY FOR TARGETED DRUG
DELIVERY AND PERSONALIZED MEDICINE
TECHNOLOGIES

Focusing on using engineering nanotechnology for medical applications, Prof. Avi Schroeder creates nano-sized targeted drug delivery systems to improve cancer treatments and to treat neurodegeneration, including Parkinson's disease and Alzheimer's.

Research in the lab harnesses artificial intelligence and robotics to develop innovative therapeutic nanotechnology solutions that offer unprecedented precision and efficacy. By utilizing targeted nanoparticles, the team enhances drug delivery to specific organs and tissues, thereby minimizing side effects and improving patient outcomes.

Nanotechnology in Drug Delivery and Cancer Therapy

Schroeder's team has made significant contributions in the field of drug delivery, particularly the development of targeted nanomedicines. By engineering nanoparticles that can carry drugs directly to specific tissues or cells, their research seeks to minimize side effects and enhance

therapeutic outcomes. This is especially relevant in cancer treatments, where traditional approaches harm healthy cells. Schroeder's nanoparticles are designed to release drugs only at the tumor site, reducing toxicity and improving patient recovery.

A focus of the lab is the treatment of metastatic breast cancer. The team has developed lipid-based nanoparticles that deliver advanced medications to hard-to reach metastatic sites, such as pancreatic cancer.

Schroeder is the co-inventor of MM-II, an innovative medicine for treating osteoarthritis. Schroeder and colleagues from Technion and other institutions developed unique particles that act as joint lubricants, reducing pain and improving patient mobility. The medicine has already helped many patients with osteoarthritis worldwide.

Brain Diseases

Schroeder is a pioneer in the use of nanotechnology for brain malignancies and Parkinson's disease. His lab develops "nano-factories" — minuscule

devices that can deliver drugs and adapt treatments in real-time based on a patient's response. By integrating diagnostics and therapeutics into a single platform - theranostics, this approach not only treats but also monitors disease progression. This capability is especially promising in neurodegeneration, where early detection and precise intervention can significantly improve survival rates.

Environmental and Sustainable Applications

Beyond medicine, Schroeder's interest in nanotechnology extends to environmental sustainability. His team is exploring ways to use nanoparticles in agriculture, such as smart fertilizers that reduce environmental waste or treat viral diseases in crops. These innovations aim to address global challenges in food security with minimal ecological footprints.

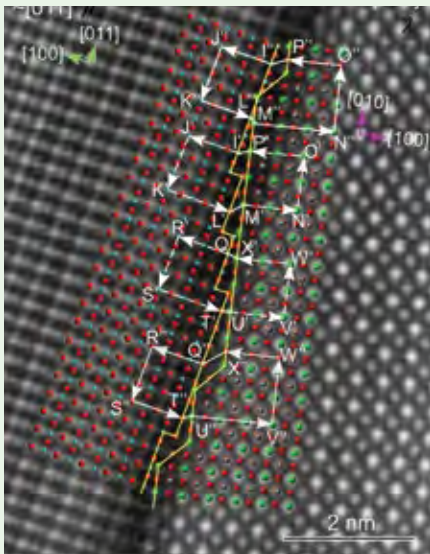
Prof. Schroeder's nanotechnology research is at the intersection of medicine, biology, and sustainability. His innovative work in targeted and personalized medicine, and environmental applications continues to push the boundaries of nanotechnology, offering promising solutions to critical challenges in healthcare and beyond.

He has been recognized with numerous awards for his contributions to nanotechnology and biomedical research.



Prof. Wayne D. Kaplan's research in nanotechnology has focused on the role of interfaces in nanometer-scale microstructures. From a fundamental scientific perspective, this research has examined the correlation between gradients in order and chemistry perpendicular at interfaces, and how these gradients relate to excess energy and adhesion, and the kinetics of interface motion.

Advanced electron microscopy and associated spectroscopy were employed to analyze the structural and chemical gradients, as well as to directly measure chemical excess. This work was conducted using the suite of electron microscopy tools available at the Russell Berrie Nanotechnology Institute, with a special emphasis on the monochromated and aberration-corrected scanning transmission electron microscope, which offers atomic resolution. These measurements were then correlated with the observed values of excess interface energy, expanding the conventional understanding of adsorption.



Energy measurements at solid-liquid interfaces were conducted using controlled high-temperature wetting experiments (up to 1800°C). Solid-solid interface energy measurements were made by characterizing the convoluted equilibrium shapes of two single crystals in contact and at equilibrium, using electron microscopy. Various atomistic simulations were used to explore key trends in structural ordering, particularly at solid-liquid interfaces, although more engineering-relevant findings emerged from solid-solid wetting experiments.

While initial experiments focused on metallic single crystals in contact with ceramic single crystals (often through dewetting experiments), significant effort was dedicated to applying these results to metal-reinforced ceramic nanocomposites.

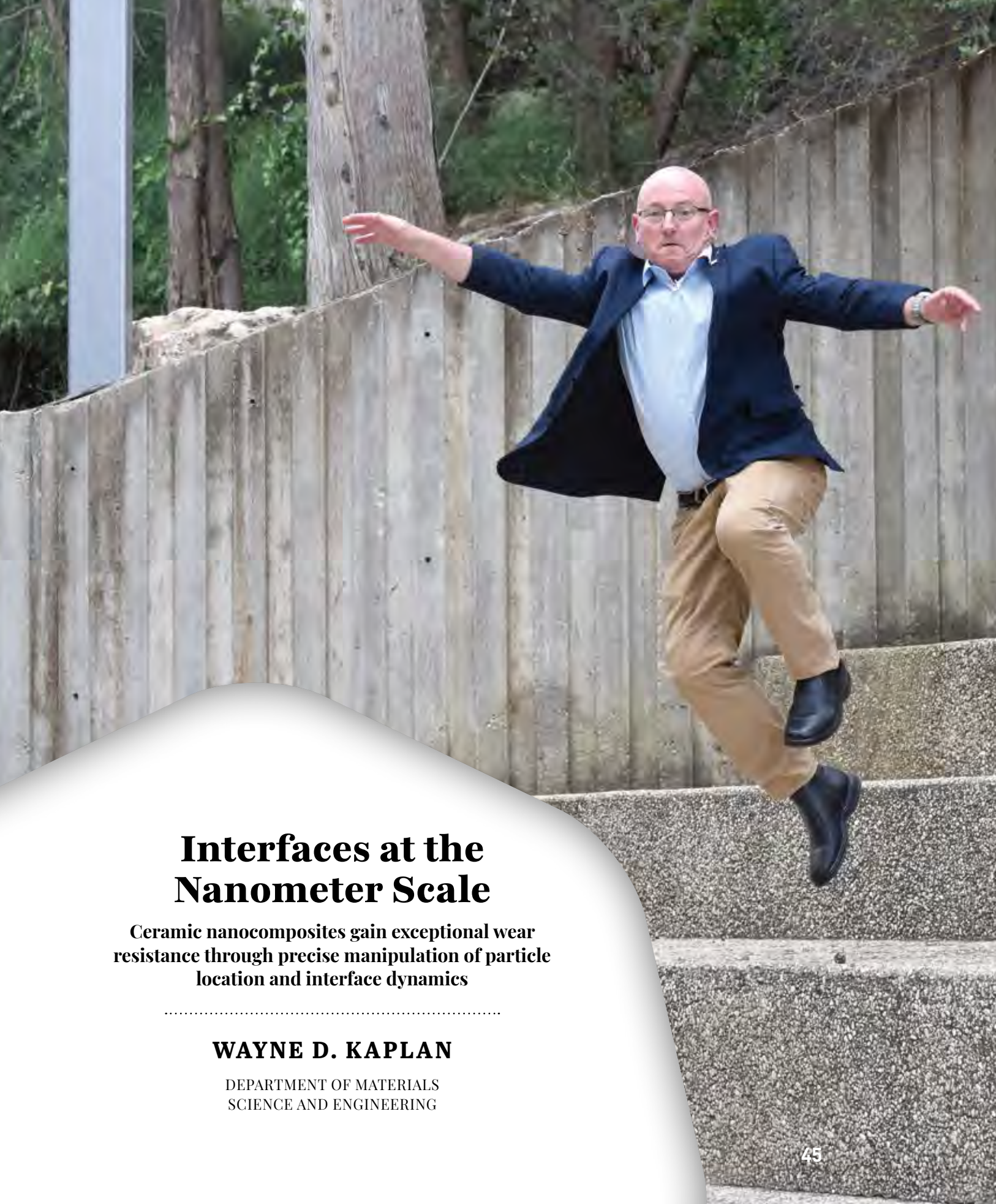
In these materials, residual stress fields, arising from differences in the thermal expansion coefficients of the constituents, can be harnessed to significantly increase the strength of the ceramic (up to a threefold increase), provided that the location of particles within the microstructure is carefully controlled. Additionally, it was discovered that the

wear resistance of ceramics could be significantly improved using these principles. This improvement was achieved by controlling the relative velocity of ceramic grain boundaries compared to the velocity of particles moving with the boundaries during grain growth.

As a result, a major focus of the research has been measuring the normalized velocity of grain boundaries and interfaces as a function of dopant adsorption, an effort that heavily relies on the electron microscopy facilities at Technion. Of critical importance, and the focus of ongoing research, is the mechanism by which grain boundaries move and how this movement is influenced by the adsorption of dopants and impurities.

It was discovered that the wear resistance of ceramics could be significantly improved by controlling the relative velocity of ceramic grain boundaries

High-angle annular dark-field (HAADF) scanning transmission electron micrograph (STEM) of an edge-on general grain boundary in SrTiO₃. The grain on the left is close to a zone axis, and the grain on the right is in the [001] zone axis. The micrograph was filtered to remove noise (average background subtraction). Nanometer-length-scale steps are visible along the boundary (marked in yellow). These steps are linear defects called disconnections, whose movement is the mechanism for migration of the grain boundary, and thus the mechanism for grain growth in polycrystalline materials. In the atomistic solution, green circles represent Sr, red circles represent O, and blue circles represent Ti. Reproduced from H. Sternlicht, W. Rheinheimer, A. Mehlmann, A. Rothschild, M. J. Hoffmann, and W. D. Kaplan, "The Mechanism of Grain Growth at General Grain Boundaries in SrTiO₃," *Scripta Materialia*, 188: 206–211, 2020.

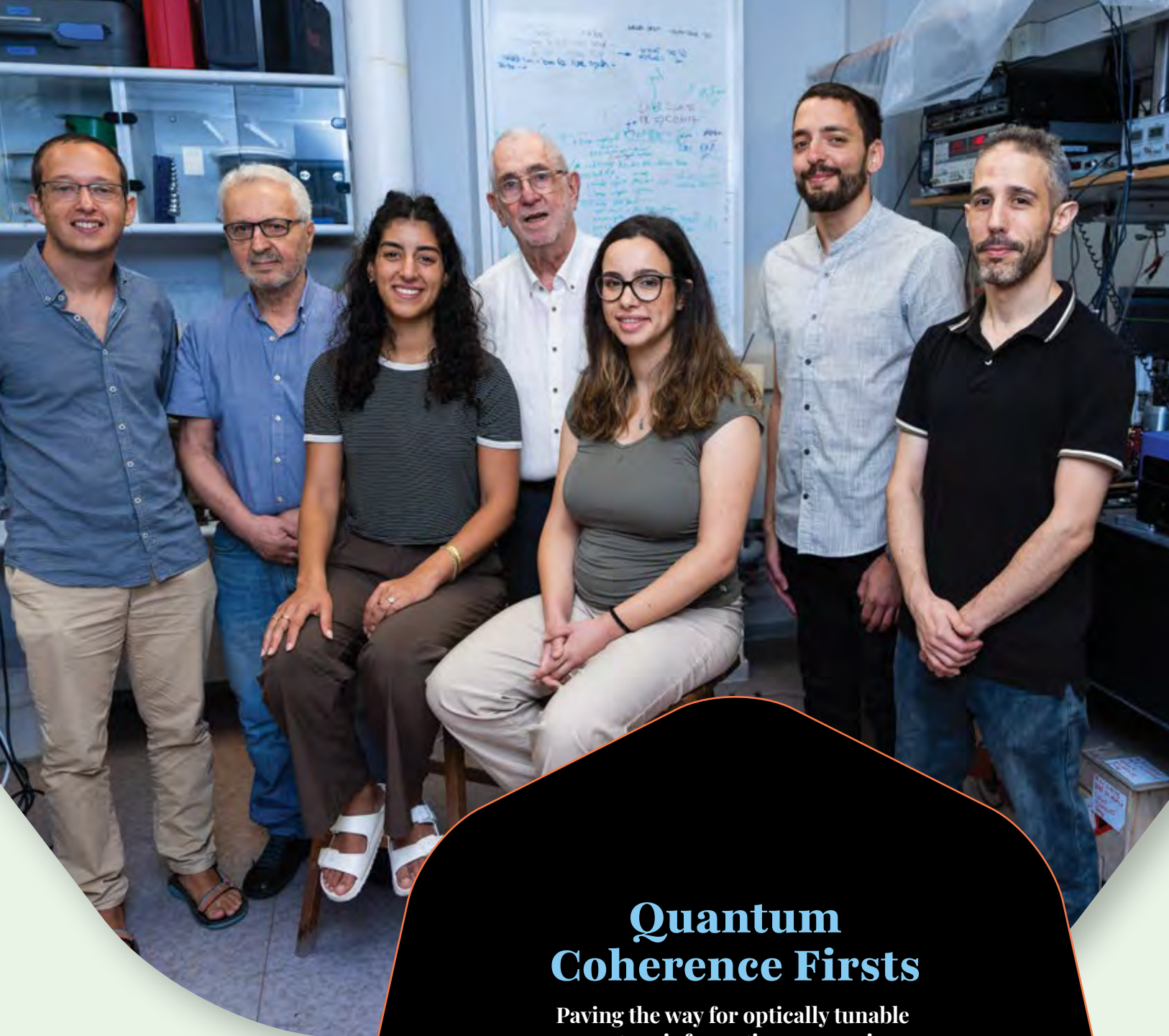


Interfaces at the Nanometer Scale

**Ceramic nanocomposites gain exceptional wear
resistance through precise manipulation of particle
location and interface dynamics**

WAYNE D. KAPLAN

DEPARTMENT OF MATERIALS
SCIENCE AND ENGINEERING



The Eisenstein team
(l-r) Dr. Igor Khanonkin, Dr. Visorian 'Besov' Mikhelashvili, Noa Goeli, Prof. Gadi Eisenstein, Inbal Rapaport, Ori Gabai, and Dr. Amnon Willinger.

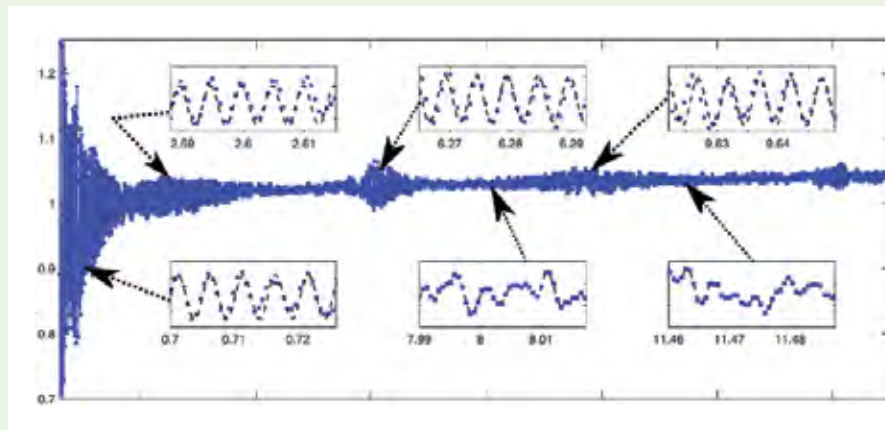
Quantum Coherence Firsts

Paving the way for optically tunable quantum information processing

GADI EISENSTEIN

DIRECTOR, RUSSELL BERRIE
NANOTECHNOLOGY INSTITUTE

VITERBI FACULTY OF ELECTRICAL
AND COMPUTER ENGINEERING



Eisenstein's team demonstrated coherence revival in a QD gain medium. After an initial collapse at approximately 1.5 ps, the coherence revives four times and the phenomenon lasts up to 14.5 ps.

Prof. Gadi Eisenstein and his team achieved the first room-temperature demonstration of quantum coherence phenomena—such as Rabi oscillations, Ramsey fringes, photon echoes, and coherence revival—in a solid-state quantum dot (QD) optical amplifier operating at 1550 nm. Their experiments revealed unprecedented coherence and dephasing times and demonstrated that quantum behavior in QDs can be precisely manipulated through advanced pulse shaping, paving the way for optically tunable quantum information processing.

A series of quantum optic experiments were performed using an InAs/InP QD optical amplifier operating at 1550 nm. The experiments were complemented by a comprehensive semiclassical model, where pulse propagation is described using Maxwell's equations, and the interaction with the QDs is modeled using the Schrödinger equation in the density matrix formalism.

A sufficiently narrow and intense single pulse induces Rabi oscillations. These manifest themselves as a transformation from a regular pulse to a double humped signal, where the peaks represent the state of gain, and the valley denotes absorption. The characteristics of the Rabi oscillations can be controlled by pulse shaping, where a linear chirp can either diminish or significantly enhance the Rabi oscillations.

Injection of two pulses with a controlled mutual delay induces Ramsey fringes. Clear fringes, with a period equal to an optical cycle, were observed in both the amplitude and the phase of the delayed pulse. Varying the nominal delay between the pulses yields fringes with changing contrast, enabling extraction of the coherence time of the QDs.

Photon echo experiments were performed to discriminate between the coherence time, governed by the inhomogeneously broadened gain of the QDs, and the pure dephasing time. These experiments yielded an unprecedented room-temperature dephasing time of 5.2 ps and a coherence time of 1.2 ps.

Finally, Eisenstein's research team demonstrated the unique phenomenon of coherence revival. This peculiar

effect was first predicted by Eberly in 1980, who theorized that number states which decohere may fully revive after some time, and that the effect can repeat itself many times. Experimental demonstrations were reported more than a decade later, but never in a solid state nor at room temperature.

The revival originates from the interaction among five homogeneously broadened spectral regions that overlap with the excitation pulse spectrum, similar to the interaction of number states in Eberly's original theory.

The revival pattern can be controlled by shaping the excitation pulse. A simple change in pulse amplitude, as well as a complex amplitude and phase shaping, yields controllable patterns leading to an optically tunable quantum code.

Did You Know?

NANOSTRUCTURED SEMICONDUCTOR-BASED PHOTONIC DEVICES, such as quantum dot (QD) lasers and amplifiers, hold the promise of ultimate laser capabilities by mimicking atom-like media. This leads to unprecedented static and dynamic properties, including very low sensitivity to temperature changes.

Beyond their practical applications, QDs serve as a crucial platform for quantum optics. Low temperature single QDs provide the most efficient single-photon on-demand sources and support various quantum sensing schemes. Additionally, QD photonic devices play a key role in room temperature quantum optic systems.

The coherence time of room temperature QDs is of the order of 1 ps. To observe quantum optic phenomena, it is necessary to induce and measure a quantum effect within a time scale shorter than 1 ps. This can be achieved by using optical pulses with durations shorter than 100 fs to excite a room-temperature QD optical amplifier, with the output characterized using Frequency-Resolved Optical Gating (FROG) or Cross-FROG (X-FROG).



Spinning Quantum Light

Exploring spin-optical phenomena and
spin-valley lasers at the nanoscale

EREZ HASMAN

FACULTY OF MECHANICAL ENGINEERING
ATOMIC-SCALE PHOTONICS LAB



Since the late 2000s, Prof. Erez Hasman has headed the Atomic-Scale Photonics Laboratory, where the fields of spinoptics and the photonic Rashba effect have been researched. Hasman initiated and demonstrated the first geometric phase metasurface in 2001, pioneering the field of optical metasurfaces. His group first reported the “Optical Rashba Effect” in engineered metasurfaces back in 2013. The team have consistently published high-impact papers in *Science* and *Nature*, describing for the first time effects like the Pancharatnam–Berry phase utilizing metasurfaces, photonic spin Hall, random Rashba, photonic Aharonov-Bohm, spinoptical quantum sources, and Brownian spin-locking phenomena. In 2023, Hasman’s team were the first to realize a spin-valley Rashba monolayer laser at room temperature, utilizing spin-split photonic modes in a WS₂ microcavity.

Spin-valley Rashba Monolayer Laser

In 2023, the Hasman research group reported a coherent and controllable spin-optical monolayer laser by incorporating a WS₂ monolayer into a heterostructure microcavity supporting high-Q spin-valley resonances, without requiring magnetic fields or cryogenic temperatures.

In the Hasman lab, the spin-valley microcavity was constructed by interfacial an inversion-asymmetric photonic spin lattice core with an inversion-symmetric cladding for laterally confined spin-valley states. Inspired by valley pseudospins in monolayers, the high-Q spin-valley states are created via the photonic Rashba-type spin splitting of a bound state in the continuum, which remains highly confined in space due to symmetry mismatch between its near field and outgoing propagation field. A WS₂ monolayer serves as the gain material due to its strong exciton binding energies and unique valley pseudospins. Specifically, the valley excitons can be selectively excited using spin-polarized pump light, enabling active control of the sources without magnetic fields.

Within the monolayer-integrated microcavity, the populated valley excitons couple with the spin-valley states due to polarization matching, enabling the spin-optical lasing through strong optical feedback. Importantly, the lasing mechanism leads to the long-sought valley coherence in the WS₂ monolayer without the need for cryogenic temperatures. The lasing intensity and spatial coherence are controlled by different pump polarizations.

The photonic spin-valley Rashba effect provides a general mechanism for constructing surface-emitting

The team were the first to realize a spin-valley Rashba monolayer laser at room temperature, utilizing spin-split photonic modes

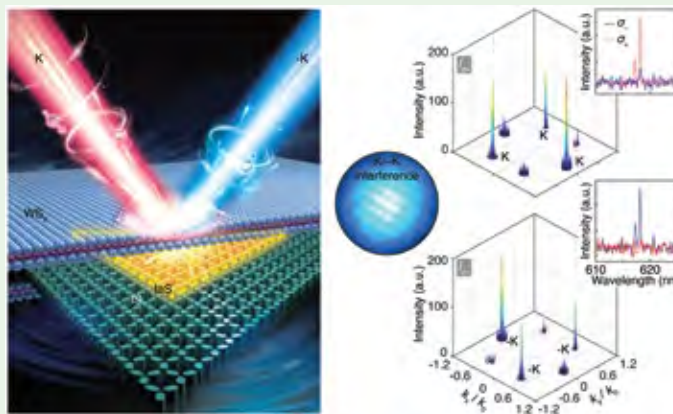
spin-optical light sources. Hasman envisions the monolayer-integrated spin-valley microcavities as a multidimensional platform to study coherent spin-dependent phenomena in both classical and quantum regimes by exploiting electron and photon spins.

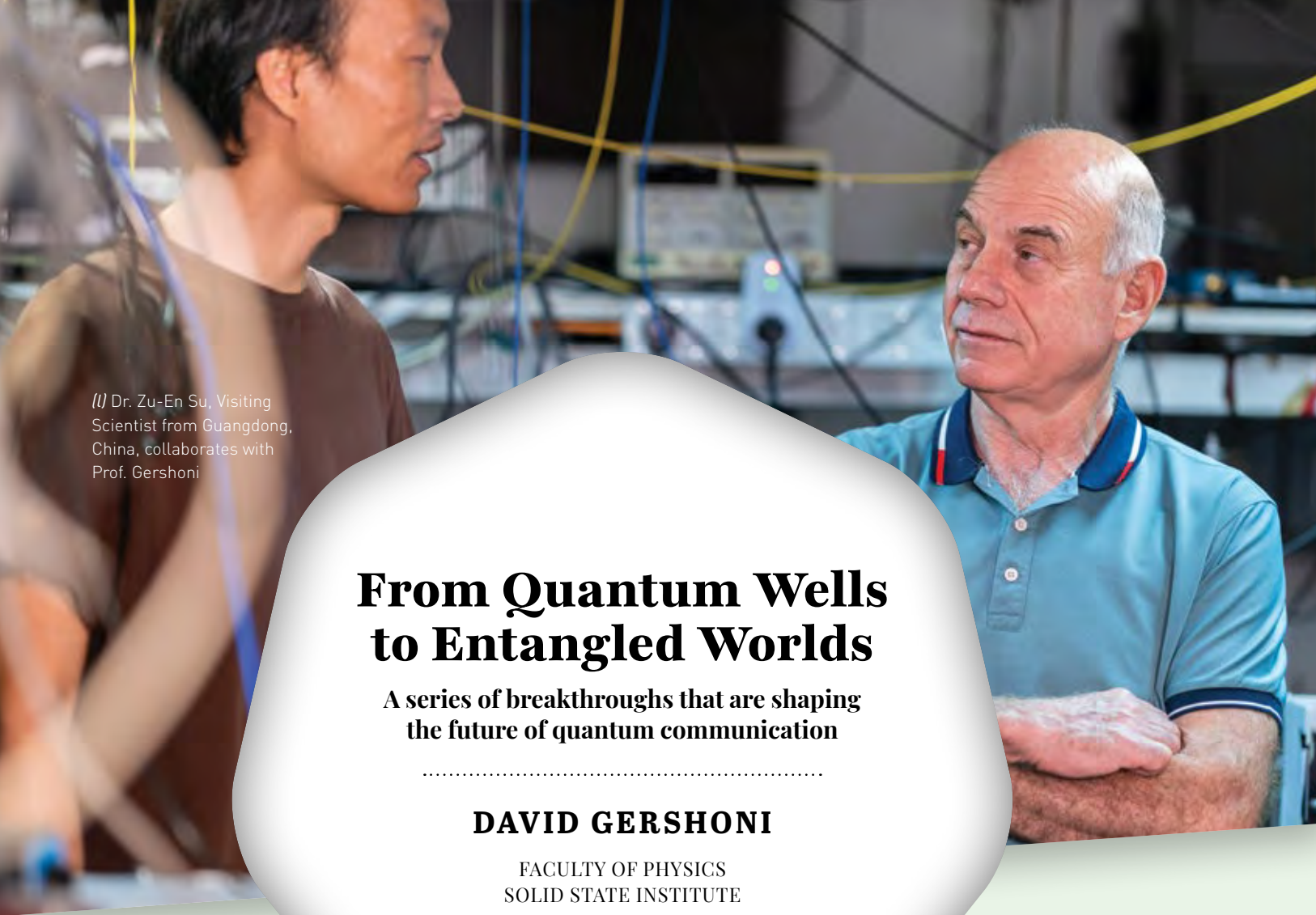
Did You Know?

BOTH ELECTRONS AND PHOTONS POSSESS AN INTRINSIC ANGULAR MOMENTUM,

known as spin, which has been extensively investigated in spintronics and spin-optics from fundamental research to applications. Interestingly, spin-optical light sources combine electronic transitions and photonic modes, enabling the exchange of spin information for advanced optoelectronic devices. The prerequisite for spin-degeneracy removal is usually accomplished through magnetic fields under Faraday or Zeeman effects, although miniaturization and strong magnetic fields pose challenges.

Left: Illustration of spin-valley Rashba monolayer laser. *Middle:* Lasing-mechanism-driven valley coherence. *Right:* Highly spin-polarized $\pm K$ directional emission in momentum space.





(l) Dr. Zu-En Su, Visiting Scientist from Guangdong, China, collaborates with Prof. Gershoni

From Quantum Wells to Entangled Worlds

A series of breakthroughs that are shaping the future of quantum communication

DAVID GERSHONI

FACULTY OF PHYSICS
SOLID STATE INSTITUTE



Prof. David (Dudi) Gershoni's research group focuses on the study of semiconductor quantum structures of lower dimensionality, such as quantum wells, quantum wires, and quantum dots, leading to a series of seminal works and world breakthroughs. These nanometric-size quantum structures are investigated using low-level light optics with state-of-the-art spatial and temporal resolutions. The group's

experimental expertise is built on their strong theoretical foundations in semiconductor physics, quantum optics, and quantum information processing.

Over the past two decades, the group's primary focus has been to develop new sources of "entangled light" based on semiconductor quantum dots.

The group's pioneering achievements, each representing the first demonstration of its kind and published in leading journals, include:

- Demonstrated emission of entangled photon pairs from a single semiconductor quantum dot (2006).
- Demonstrated that the spin state of the quantum dot confined exciton (an electron hole pair) can be deterministically "written" using a single optical pulse. The group showed that the pulse

polarization is directly translated into the phase of the coherent superposition of the two exciton spin eigenstates (2011).

- Showed that the exciton state can be universally gated (controlled) with one resonant picosecond long optical pulse (2011, 2012).

- Showed that the optically forbidden “dark” exciton in quantum dots, is a coherent qubit (2010), with coherence time which is longer than 100 nsec (2015), and that its spin state can be deterministically “written” by an optical pulse. In addition, the group showed that the dark exciton spin state can be gated using single picosecond long resonant optical pulses (2015).

- Demonstrated deterministic generation of a cluster state of multiple polarization-entangled photons using the dark exciton as an entangler (2016).

- Demonstrated that the polarization states of the emitted photon pair in the biexciton-exciton radiative cascade are maximally entangled (2017).

- Measured the depolarization of 3 electronic spin qubits (namely electron, hole and dark exciton) confined in the same semiconductor quantum dot (2018).

- Demonstrated supersensitive optical phase measurement using a deterministic source of entangled multiphoton states (2020).

- Developed a new method for complete state tomography of a quantum dot spin qubit (2020).

- Demonstrated a semiconductor quantum dot-based device where the confined hole spin functions as a “needle” in a quantum knitting machine, generating single indistinguishable

photons at a sub-gigahertz repetition rate. These photons are continuously and deterministically produced, all polarization-entangled with each other and with the spin in a one-dimensional cluster state with entanglement length of about 10 qubits (2023). By projecting two nonadjacent photons onto circular polarization bases, the group disentangles the spin from the intermediate photons, transforming the cluster into

an all-photonic cluster — an essential resource for quantum communication (2024).

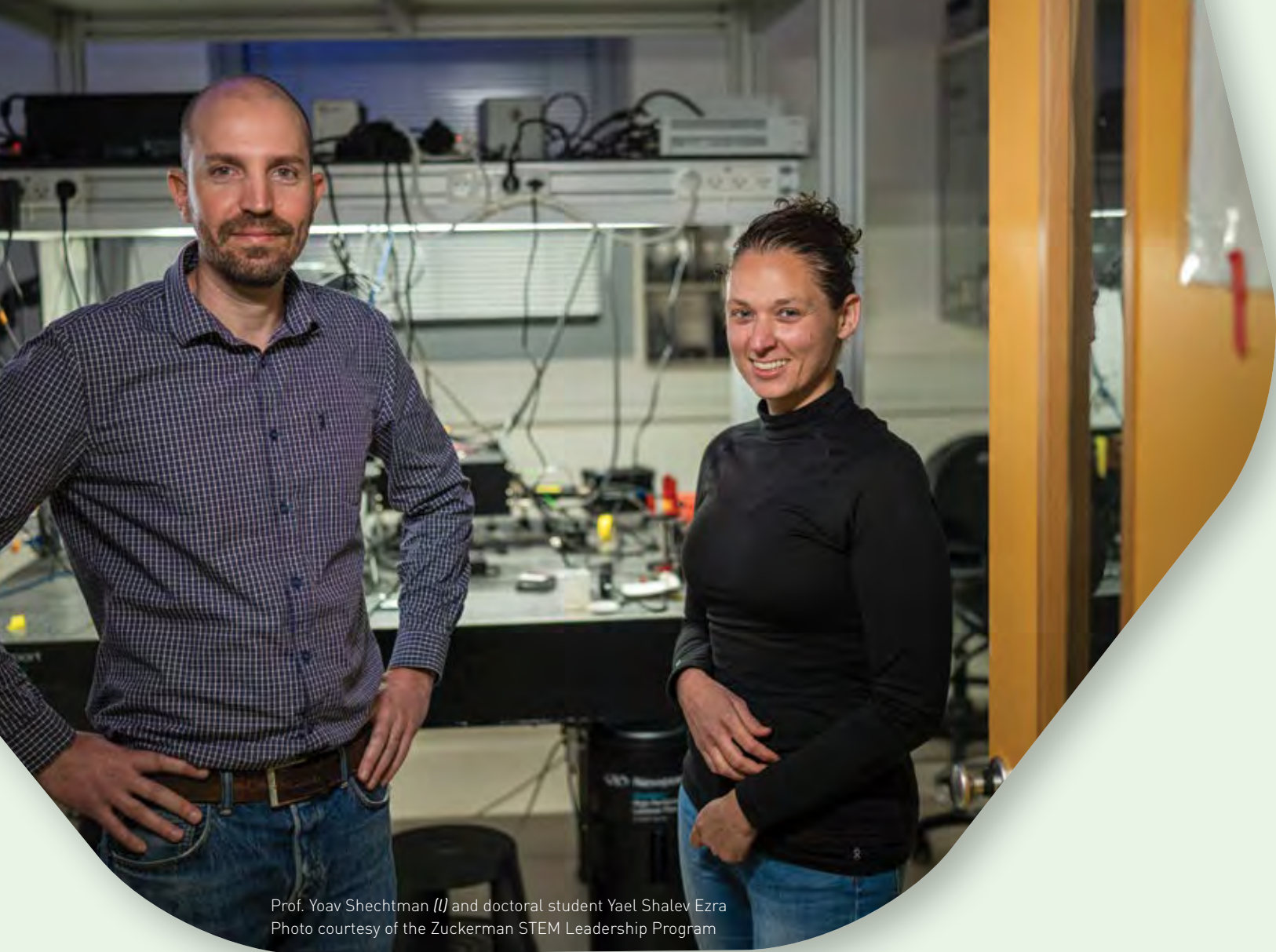
Gershoni’s group continues to push forward the frontier of enhanced quantum light sources and repeaters for quantum communication, providing the foundations for measurement-based photonic building blocks for quantum computing.



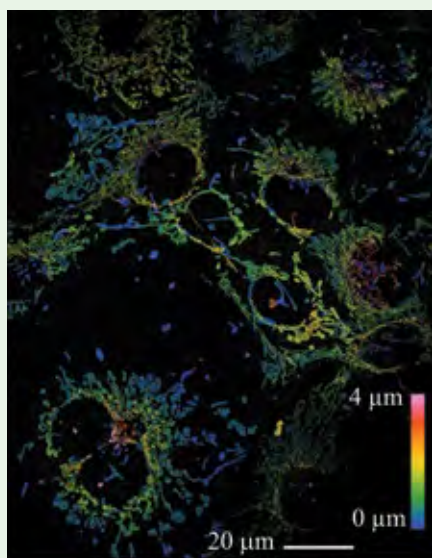
Prof. Ido Schwartz collaborates with Prof. Gershoni

Did You Know?

ENTANGLEMENT BETWEEN PARTICLES is a basic concept in quantum science. The controlled production of entangled particles is essential for future quantum technology. Entanglement between light particles—photons—is critical for quantum communication, due to their non-interactive nature and long-lasting coherence. Resources producing entangled multi-photon cluster states will enable communication between remote quantum nodes, since the built-in redundancy of cluster photons allows repeated local measurements, compensating for losses and probabilistic measurements. For practical applications, the cluster generation should be fast, deterministic, and most importantly, its photons must be indistinguishable. This is essential for permitting measurements and fusion of clusters by interfering photons.



Prof. Yoav Shechtman (l) and doctoral student Yael Shalev Ezra
Photo courtesy of the Zuckerman STEM Leadership Program



3D super-resolved mitochondria over a large field of view with high fidelity. Color encodes depth." D. Xiao, R. K. Orange, N. Opatovski, A. Parizat, E. Nehme, O. Alalouf, Y. Shechtman. "Large-FOV 3D localization microscopy by spatially variant point spread function generation". *Science Advances* 10, (2024)

Deep Learning for Super-Resolution Microscopy

Applying AI to revolutionize single-molecule localization microscopy

YOAV SHECHTMAN

FACULTY OF BIOMEDICAL ENGINEERING
NANO-BIO OPTICS LAB



Notable achievements of Prof. Yoav Shechtman's research group include applying deep learning to a variety of algorithmic challenges in SMLM and related topics.

∴ Localizing fields-of-view densely filled with fluorescent molecules, enabling faster image acquisition for SMLM. This is done by training a neural net to recover high-resolution images, given low-resolution images comprising randomly positioned emitters. [2018]

∴ Generating a super-resolution video directly from a blinking video, enabling live-cell super-resolution microscopy. This approach for x-y-t interpolation, termed DBlink, is implemented by relying on long-time correlations between frames, and training a recurrent neural network on relatively simple simulated localization maps. [2023]

∴ Localizing dense molecules in 3D in a PSF-engineered microscope, trained on simulated images of molecules in 3D, using an experimentally calibrated image-formation model. [2020]

∴ The neural net was used to find the optimal phase mask pattern for dense 3D SMLM. In dense cases, the imaging path can be split into two parallel channels, each encoded by its own phase mask, which can be jointly learned with the help of a neural net. [2021]

∴ Determining the diffusion type of single particles directly from their trajectories, using a neural net. [2019]

∴ Finding optimal spectrally encoding phase masks for single emitter position and color estimation. [2019]

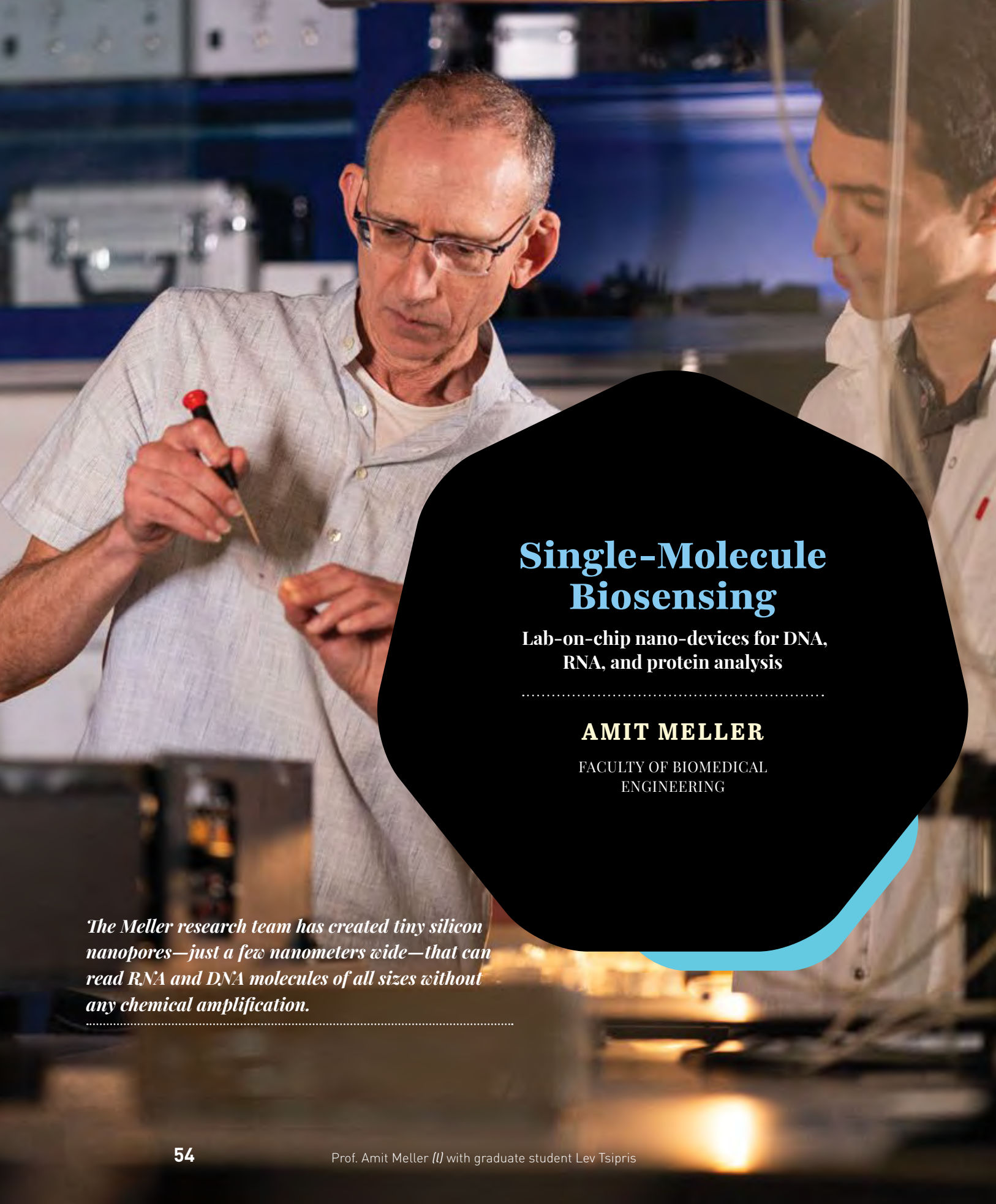
∴ A new method to fabricate phase masks based on 3D printing combined with near-index matching, leading to fast and simple fabrication of phase masks with optical properties comparable to expensive state-of-the-art masks. [2021, 2023]

Did You Know?

SINGLE-MOLECULE LOCALIZATION MICROSCOPY (SMLM) is a super-resolution microscopy method that is appealingly simple, which only requires a standard high numerical aperture microscope and a computer. It works by capturing a sequence of standard diffraction-limited images of a fluorescently-labeled sample, where, at each point in time, a small subset of the molecules labeling the sample are emitting light. The end result is a movie, consisting of thousands of frames with random spots. Each spot is localized with a precision of tens of nanometers, assuming each spot originates from a single molecule, and the resulting data is rendered into a single super-resolution image.

One of the ways to extend SMLM to 3D is to use point-spread-function engineering. A molecule no longer appears as a single spot that becomes blurry upon defocus, like in a standard microscope, but it now has some distinct shape that efficiently encodes its depth, which can then be recovered algorithmically.

During the last decade, deep learning has revolutionized signal and image processing, and microscopy is no exception. It has improved efficient image denoising, segmentation, and multimodal registration. Supervised deep learning methods can learn image reconstruction directly from optically encoded data, significantly reducing the effort previously required for image decoding.



Single-Molecule Biosensing

Lab-on-chip nano-devices for DNA,
RNA, and protein analysis

AMIT MELLER

FACULTY OF BIOMEDICAL
ENGINEERING

The Meller research team has created tiny silicon nanopores—just a few nanometers wide—that can read RNA and DNA molecules of all sizes without any chemical amplification.



Prof. Amit Meller's team pioneers the development of novel technologies for single-biomolecule sensing using advanced nano-devices capable of separating, linearizing, and scanning individual DNA and protein biomolecules on low-cost and miniature platforms.

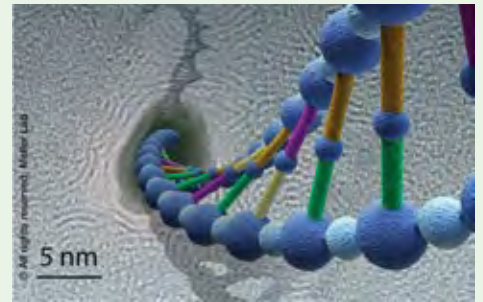
The Meller lab has developed silicon-based nanopore biosensors, only a few nanometers in size, that can directly sense unamplified RNA and DNA, RNA, and protein molecules. These devices detect sequences from short micro-RNAs (miRNAs) of a few tens of nucleotides to genomic DNAs spanning hundreds of thousands of base pairs. Unlike most nucleic acid sensing methods that require amplification (e.g., PCR) and risk introducing bias, the Meller lab's nanopore technologies detect native DNA, greatly broadening their biomedical applications, and preserving key biological information lost in molecular amplification.

The team recently showed that its solid-state nanopore biosensors can distinguish individual full-length proteins after denaturation with an ionic surfactant. This enables low-cost, digital protein fingerprinting and counting without relying on expensive antibodies or affinity probes, while allowing high multiplexing. Supported by ERC-ADG funding, the lab is advancing this approach to detect key post-translational modifications (PTMs) in proteins.

The lab extends its work to real-world applications. In collaboration with Rambam Hospital, the Meller team integrated nanopore devices with lab-on-chip microfluidics to develop a portable SARS-CoV-2 diagnostic unit based on mRNA quantification, fully bypassing costly and error-prone PCR.

Supported by the Israel Innovation Authority, the Meller Lab is pioneering advanced biochemical tests and fluidic technologies for detecting single molecules in biofluids, aiming to revolutionize early disease diagnosis. As part of the Liquid-Bx "Magnet" consortium, the lab partners with innovative Israeli startups: Salignostics to identify pancreatic cancer markers in saliva; Sensera to detect nucleosome-based cancer biomarkers from minimal blood samples; and Minovia to precisely measure mitochondrial DNA for diagnosing cancer and Alzheimer's disease.

The Meller Lab has developed an innovative technology for separating and identifying single proteins using custom-designed silicon nanochannels. Unlike traditional antibody or peptide-based methods, which struggle with low protein quantities, this technique allows simultaneous separation and tracking of individual protein molecules. Proteins are labeled with dual amino acid-specific tags and separated by their mass-to-charge ratio as they move through ultra-small silicon channels. Paired with ultra-sensitive single-photon microscopy, this method quickly analyzes thousands of proteins by monitoring their



A schematic illustration of DNA molecule threaded through a silicon nanopore (image created using high resolution TEM).



movement patterns. Funded by an ERC Proof of Concept grant, the lab is using this technology to measure protein biomarkers for predicting and monitoring treatment responses in Age-Related Macular Degeneration (AMD), in partnership with Hadassah Medical Center.

Did You Know?

EMERGING SINGLE-MOLECULE DNA AND PROTEIN SENSING TECHNIQUES are ushering in a transformative era, expected to impact both basic research as well as applied biomedical applications ranging from biomarkers-based clinical diagnostics to precision medicine. Some predict that the impact of single-molecule protein sensing techniques will supersede that of next generation DNA sequencing (NGS), as it will make single cell proteomics a routine tool just like single cell transcriptomics. Nevertheless, significant challenges remain in achieving ultra-fast full-length protein sensing, including molecular integrity loss due to protein fragmentation, biases introduced by antibody affinity, identification of a vast number of different proteoforms in the human proteome, and low throughput.



Redefining the Transistor

From perforated source
to electron nozzle

NIR TESSLER

VITERBI FACULTY OF ELECTRICAL
AND COMPUTER ENGINEERING



Vertical Transistors, and particularly the perforated source design, developed by Prof. Nir Tessler and his team, represent a significant innovation in organic electronics, especially for organic field-effect transistors (OFETs) and flexible device applications. They open new frontiers in printable electronics, low-cost sensors, and compact circuits where traditional silicon is not viable.



The Tessler team's quest for a new transistor structure was motivated by the need to achieve high currents and fast switching while using amorphous materials with very low electron and hole mobilities. These constraints were driven by their application in low-cost electronics.

Prof. Nir Tessler and Oded Globerman invented the perforated source vertical transistor (Figure 1a). Prof. Roy Shenhar, then a postdoctoral researcher, suggested block copolymer nanolithography as a low-cost fabrication method. Ariel Ben-Sasson, a Biomedical Engineering graduate who joined the team and during his PhD, advanced the concept into fully functional devices, addressing fabrication challenges and establishing the physical operating principles. Ben-Sasson then developed multiple architectures, including an ambipolar vertical transistor and perforated sources incorporating self-assembled metallic nanowires.

Michael Greenman continued this in his PhD, demonstrating the time-domain potential of the perforated source structure. He reported a switching time of 10^{-6} seconds, achieved with a semiconductor whose electron mobility is 10^5 times lower than silicon. Greenman further demonstrated monolithic vertical integration with an organic light-emitting diode, creating a "smart pixel" that serves as a basic building block for OLED displays.

These results revealed a trade-off: the

architecture provided either high-speed/high-current performance or clean transistor behavior with ideal saturation, but not both simultaneously. Addressing this limitation became the focus of Gil Sheleg's doctoral work. Using 2D semiconductor device simulations, Sheleg examined electric field and current flow in the structures. He concluded that conventional scaling approaches were unsuitable for low-cost applications and instead developed a new device concept that functioned as an electron nozzle.

This design, termed the *double work-function (DWF)* transistor, was validated in a lateral configuration. Figure 1b shows an SEM image of the fabricated device. The structure consists of a 100 nm silicon oxide (SiO_2) gate insulator, a 30 nm indium gallium zinc oxide (IGZO) semiconductor layer, and two top electrodes separated by 200 nm defining the channel length.

To illustrate device operation, simulated electron density was superimposed on the IGZO (Figure 1b). High electron density, shown in dark red, accumulates as the gate pumps charge from the Mo electrode. This build-up generates diffusion pressure that pushes electrons laterally beneath the Pt region toward the drain. The effect is analogous to fluid flow through a pressure nozzle, with the drain acting as a semi-passive sink that prevents current clogging.

The progression from the perforated source to the electron nozzle transistor represents a sequence of fundamental

architectural advances. These designs demonstrate that transistor performance can be engineered through electrode geometry and work-function engineering, enabling high-speed operation in low-cost, low-mobility materials.

The most rewarding part has been seeing students continue to excel: Ariel Ben-Sasson, Co-Founder and CTO of ZipBio; Michael D. Greenman, Senior Electro-optics System Engineer at Nvidia; and Gil Sheleg, Senior FI and Silicon Debug Engineer at Amazon's Annapurna Labs.

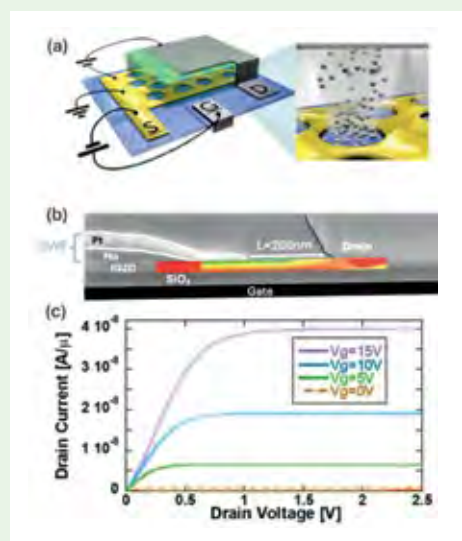


Figure 1. (a) Schematic description of the perforated source vertical transistor. The zoom shows the electron injection from the perforation. (b) SEM image of the electron pressure-nozzle transistor. We superimposed the 2D device simulation on the picture, showing the electron density as a heat map. (c) Measured output characteristics of the transistor in (b).

Redefining Clean Energy

Decoupled water splitting and nanofiber catalysis at the frontier of clean energies and materials research

GIDEON GRADER

WOLFSON FACULTY OF CHEMICAL
ENGINEERING



Over the past two decades, Prof. Gideon (Gidi) Grader's research in nanotechnology has focused on the synthesis of polycrystalline ceramic materials, and process development for green energy generation and utilization. Since 2004 his work has resulted in 84 publications in leading journals, and 9 patents.

A major breakthrough was the development of decoupled water splitting via the ETAC (Electrochemical Thermally-Activated Chemical) process. In collaboration with Prof. Avner Rotschild of the Faculty of Materials Science and Engineering, they developed nickel hydroxide-based electrodes that allowed

separation of the hydrogen evolution reaction (HER) from the oxygen evolution reaction (OER) step. The HER and OER steps can be decoupled both spatially and temporally. This discovery led to the establishment of a startup company H2Pro, in 2018, focused on scaling up hydrogen generation via decoupled water splitting.

H2Pro has raised over \$100 million and employs approximately 100 people. This breakthrough has been recognized by prestigious awards including: the Grand Scientific Prize of the Charles Defforey Foundation-Institute of France (2023), the Royal Society of Chemistry (RSC) Stephanie L. Kwolek Horizon Prize (2022), the Guy Sella Research Prize in Energy (2021), and the Eric and Sheila Samson Israel Prime Minister's Prize (2020).

Grader has also conducted research

on using electrospinning to synthesize ceramic nanofibers, including how to control their morphology and structure. This work has led to publications in important journals such as *Advanced Materials*, *Advanced Functional Materials*, *ACS Applied Materials and Interfaces*, and the *Journal of the American Ceramic Society*.

More recently, his work focused on the preparation of thermoelectric materials consisting of calcium cobaltite (CCO) and sodium cobaltite (NCO). By forming nano-ribbons, rather than round fibers, Grader's group was able to stack them precisely on a collector during electrospinning, and induce the individual grains to grow within the plane of the fibers. Coupling this special architecture with spark plasma sintering (SPS) technology, followed by spark plasma texturing (SPT), enabled



(l-r) Prof. Gidi Grader, Dr. Gennady Shter, Dr. Meirav Mann; graduate students Adi Rozenzweig and Itzik Maor

Grader's team is paving the way to new applications for efficient harvesting of waste heat at high temperatures

the group to achieve remarkable alignment and high density of the individual grains within the compact bulk material. These properties have led to a world record of the thermoelectric properties of CCO and NCO, paving the way to new applications for efficient harvesting of waste heat at high temperatures.

The significant potential of this development arises from the fact that approximately 30% of industrially classified heat is released into the atmosphere from surfaces with temperatures exceeding 673 K.

Another important research project is to create catalysts based on ceramic nanofibers for CO₂ hydrogenation and utilization. The premise of this work is based on the improved performance of catalysts when the catalytic moieties

are spread over ceramic fibers. This improvement stems from the large surface area of nanofibers, which enhances efficient catalyst exposure and effectively reduces the mass transfer resistance of the reacting species. It also enables rapid diffusion of products away from the catalytic surface, thus reducing subsequent reactions to undesired products.




Decoding Nature's Blueprint

Unlocking nature's design strategies
for advanced materials

BOAZ POKROY

FACULTY OF MATERIALS SCIENCE
AND ENGINEERING
BIO-INSPIRED SURFACE ENGINEERING
AND BIOMINERALIZATION LAB



*Pokroy's group is embedding
proteins, amino acids, and even
anti-cancer drugs into crystals
to fine-tune semiconductors and
enable targeted drug delivery.*



Studying biomineralization, Prof. Boaz Pokroy's research group explores the structure of mineralized tissues, establishing the correlation between structure and function, and applies these biological principles to engineer novel bio-inspired functional materials with unique properties.

Biostrategies for biocrystallization

Their most notable recent achievement, published in *Science*, was uncovering how the brittle star *Ophiomastix wendtii* toughens its otherwise brittle crystalline skeleton. Atomic- and nano-scale studies revealed metastable high-Mg calcite nanoprecipitates, formed through a novel process in which crystals grow at ambient conditions from a supersaturated amorphous precursor. These nanoprecipitates are crystallographically aligned with the host matrix and organized in a layered manner, inducing internal compressive stress and creating alternating stress–modulus layers that significantly enhance mechanical toughness.

Nanoporous gold

The group has translated several biological insights into synthetic materials. Inspired by the complex morphologies of many single biocrystals, they grew curved single crystals of gold with intricate complex shapes and morphologies. They showed that although these crystals have no facets, and consist of nanometer-sized ligaments in a highly porous network, they diffract as perfect single crystals. They developed an energetic model, which suggests that the reason such single crystals are formed is that their growth rate is faster than their nucleation rate within

a given volume, an insight with direct implications for catalysis.

Nanoporous gold is a promising catalytic material, but conventional production by dealloying polycrystalline gold alloys yields grain boundary-rich thermally unstable catalysts that degrade under operating conditions. Instead, the group developed self-formed nanoporous single crystalline gold, free of grain boundaries and with more stable surfaces, resistant to coarsening at high temperatures. They further showed that when the gold alloy undergoes severe plastic deformation during etching, semiconductor gold cyanide nanowires form within the dislocation lines, introducing new opportunities for electronic and catalytic applications.

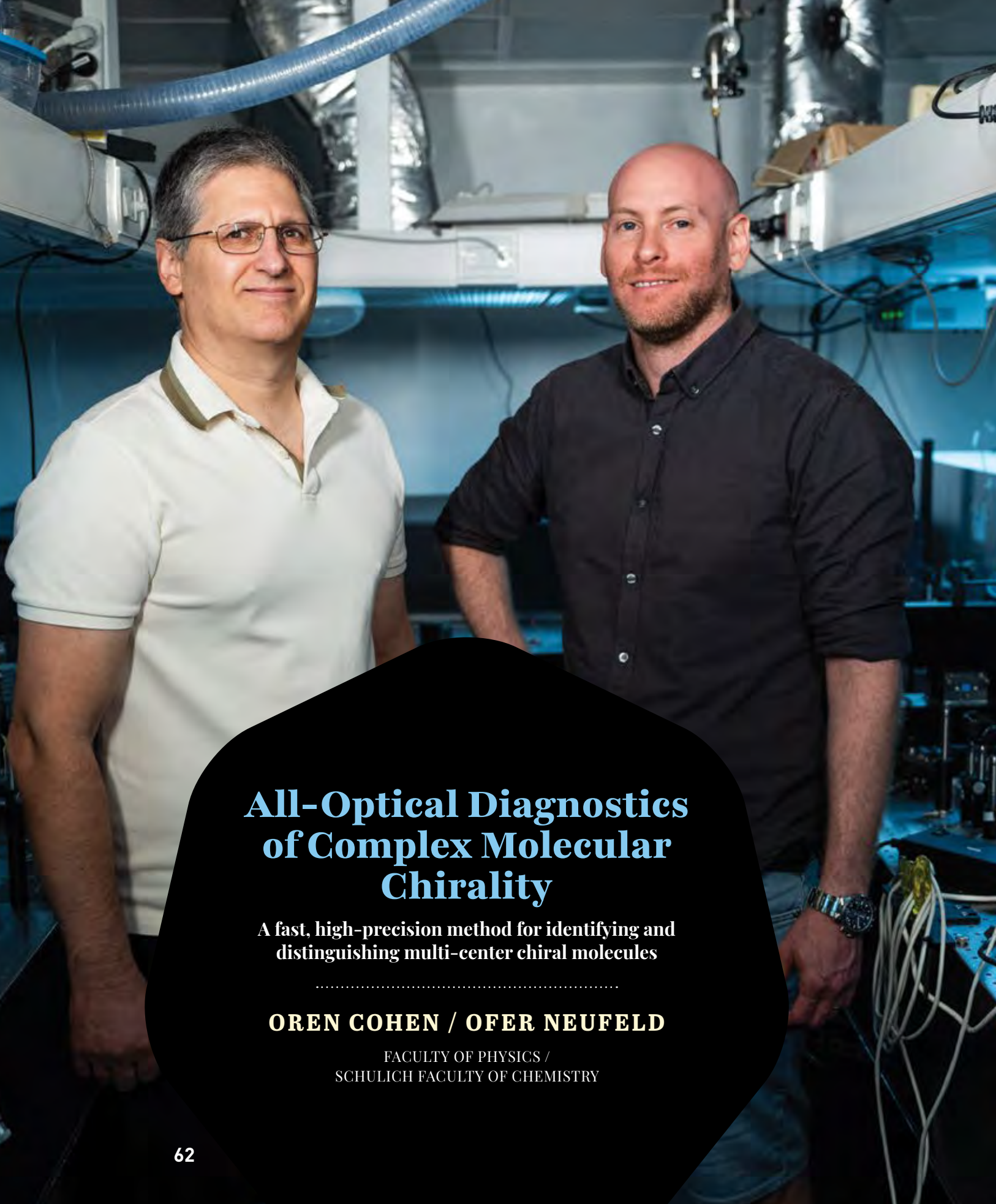
Synthesis of inorganic materials with incorporated organic molecules inspired by biomineralization, where organisms incorporate proteins into crystal lattices, the group investigated the synthetic embedding of organic molecules into inorganic crystalline hosts. They demonstrated that a recombinant biomineralization fusion protein integrates into the lattice of calcite, and that even single amino acids can also be incorporated. They further showed that amino acids can also enter semiconductor lattices, significantly shifting the band gap and providing a new approach to tune semiconductor properties. Additionally, they showed that graphene oxide can be embedded into calcite single crystals and impart fluorescence to calcite crystals, anti-cancer drugs can be incorporated into calcite crystals for controlled release, and amino acids can be integrated into gold single crystals.

Controlling short-range order of amorphous precursors

Another biostrategy that provided valuable insights involves the control organisms exert over the short-range order of transient amorphous precursors, allowing the organism to control the desired polymorph after crystallization. Building on this concept, the group investigated the ability to control the short-range order of nanometric thin amorphous film grown by atomic layer deposition. For the first time, it was demonstrated that surface stress strongly affects the short-range order of amorphous ceramics, resulting in an increase of up to 20% in the density of thin amorphous films. This densification produced measurable changes in both the dielectric and refractive indices of thin alumina films, only several nanometers thick. This discovery has implications for the microelectronics industry in the fabrication of gate dielectrics.

Biocrystallization of wax crystals

The group studied the biocrystallization of nanometric wax crystals on plant cuticles, focusing on broccoli leaves. By controlling strain during deposition, they were able to predefine crystal morphology, size, and density. The resulting wax coatings fully prevented biofilm formation for over two weeks in bacterial medium. This breakthrough opened a new research field, secured an ERC Proof-of-Concept grant, and led to a patent application. Building on this, the team developed SafeWax—a coating that forms superhydrophobic wax layers on crops lacking such crystals—a bio-inspired, sustainable crop protection strategy within an EIC Pathfinder project coordinated by Prof. Pokroy.



All-Optical Diagnostics of Complex Molecular Chirality

**A fast, high-precision method for identifying and
distinguishing multi-center chiral molecules**

.....
OREN COHEN / OFER NEUFELD

FACULTY OF PHYSICS /
SCHULICH FACULTY OF CHEMISTRY



"Our revolutionary technique can fully characterize complex chiral molecules in a single rapid test — a breakthrough for drug development."

Characterizing chirality is crucial for applications in the pharmaceutical industry, as well as in the study of dynamic chemical and biological systems. However, this task remains challenging, especially due to the increasing complexity and size of molecular structures in drugs and active compounds. In particular, large molecules with numerous active chiral centers are now ubiquitous but remain difficult to analyze structurally due to their high number of stereoisomers.

A major task in modern drug development is to identify, classify, and separate, the different chiral constituents of molecules to a high precision. In fact, a new drug cannot receive FDA approval until a sufficiently pure mixture has been synthesized and characterized. However, this task has become exponentially difficult ever since drug development has moved towards larger biological molecules and chemical species that possess a high number of active chiral centers.

'Multi-center' molecules have a total of 2^N stereoisomers (isomers of the same chiral molecule that differ only by the handedness around each chiral center) to be separated. Notably, characterization of chirality in multi-center molecules is a very challenging task, because no single standard all-optical measurement is sufficient. For instance,

circular dichroism (CD) spectroscopy (which is the workhorse of the pharmaceutical industry) cannot characterize a mixture of four or more stereoisomers (i.e., $N > 1$), because signals from different stereoisomers can either cancel out or be indistinguishable. Instead, current approaches rely on an ad-hoc combination of multiple measurements from both optical and chemical methods, which are not always transferable and can be very time-consuming.

Profs. Oren Cohen, Ofer Neufeld, and their collaborators explored all-optical chiral spectroscopy for multi-center molecules using strong lasers and high-harmonic generation. They proposed the concept of locally chiral light—light that interacts with molecules as if it were itself a chiral molecule—and demonstrated that it can discriminate between different stereoisomers of molecules with multiple chiral centers by driving them to emit high harmonics. In particular, the extreme nonlinear nature of the high-harmonic generation process imprints, with a high selectivity, unique fingerprints of the handedness and structure of each chiral center onto the harmonic spectra, enables the stereoisomers to be distinguished by harmonic power measurements. By simultaneously measuring several harmonic orders, this scheme can accurately characterize the composition of

an unknown mixture of stereoisomers with high-precision, where the reconstruction is performed via a custom algorithm—either classical or deep learning-based—that the researchers developed.

Did You Know?

CHIRALITY is a property of certain molecules that makes them exist in two mirror-image forms, like left and right hands. Although these "handed" versions can look nearly identical, they can behave very differently in chemical and biological systems. In medicine, one version of a chiral molecule might be therapeutic, while its mirror image could be inactive or even harmful. Understanding and measuring chirality is essential in drug development to ensure safety, effectiveness, and precision. Scientists use advanced optical and chemical tools to detect and characterize these subtle differences, especially in complex molecules with multiple chiral centers.

A close-up portrait of a woman with long, wavy brown hair and clear safety glasses. She is looking slightly to the right of the camera with a gentle smile. Her hands are visible in the foreground, holding a small object. The background is blurred, showing what appears to be a laboratory setting with a metal railing.

Catalysis in Action

Watching molecules shape
a sustainable future

CHARLOTTE VOGT

SCHULICH FACULTY OF CHEMISTRY



Prof. Charlotte Vogt (l) with PhD student Deepraj Verma



Prof. Charlotte Vogt's research group is driven by a simple but ambitious goal: to understand and improve the chemical reactions that shape our world. Whether developing cleaner energy technologies or finding new ways to reduce greenhouse gases in the atmosphere, the team relies on advanced tools that they develop to observe chemistry as it unfolds—molecule by molecule, (micro)second by (micro)second.

One of the group's most important tool is ATR-SEIRAS--Attenuated Total Reflection Surface-Enhanced Infrared Absorption Spectroscopy developed by Vogt's team. This method allows scientists to "watch" molecules on a surface in real time as they undergo a chemical reaction. With this window into what was once invisible, the group can uncover how catalysts actually work, and use that knowledge to design more effective solutions for sustainability.

The ability to use this technique has been limited by something surprisingly simple: a tiny, specialized prism

RBNI has proven to be more than just a resource; it has become a catalyst for discovery, safeguarding research against global uncertainty and empowering bold scientific ideas to become reality.

known as an internal reflective element. These elements are the heart of ATR-SEIRAS, the very component that makes the measurements possible. Each one costs hundreds of dollars, and should ideally be disposable, since several are needed each day. During the COVID-19 pandemic, global shortages and year-long waiting times nearly brought the group's experiments to a halt.

A turning point came when Vogt approached the Russell Berrie Nanotechnology Institute (RBNI) to investigate in-house fabrication of these specialized prisms. With access to the RBNI's cleanrooms, advanced tools, and expert staff, the group learned to manufacture them in-house. What was once rare and prohibitively expensive suddenly became abundant and adaptable.

The result has been transformational. Instead of performing only one or two experiments a week, the team now conducts up to ten experiments a day, fuelling creativity and broadening possibilities.

They now test bold ideas, explore new geometries, and have invented entirely new spectroscopic methods. Students who once limited to perform fewer experiments, now embrace rapid trial-and-error—the very essence of innovation.

This independence has accelerated not only the group's own discoveries but also their ability to assist other researchers, creating a shared capability that supports colleagues in Israel and abroad. In doing so, the RBNI has proven to be more than just a resource; it has become a catalyst for discovery, safeguarding research against global uncertainty and empowering bold scientific ideas to become reality.

Norman Seiden Multidisciplinary Graduate Program in Nanoscience and Nanotechnology

212
Total

93
PhD

119
MSc

SEIDEN GRADUATES 2006 - 2024

The Norman Seiden Multidisciplinary Graduate Program in Nanoscience and Nanotechnology represents a visionary approach to graduate education. With its emphasis on excellence and innovation, the program stands as a beacon of academic and research leadership in the global nanotechnology community.

Launched in October 2005 and expanded in 2006 to include a PhD track, the Norman Seiden Multidisciplinary Graduate

Program in Nanoscience and Nanotechnology is Israel's only accredited academic program in the field. It provides an elite group of students with a "renaissance-style" education that fosters an interdisciplinary curriculum that integrates life sciences, physical sciences, and engineering preparing students to tackle the scientific and technological challenges of nanotechnology.

A Unique Interdisciplinary Approach

At the program's core is a broad curriculum that ensures students are exposed to a diverse range of disciplines, reflecting the inherently interdisciplinary nature of nanoscience. Whether students come from backgrounds in life sciences, engineering, or physical sciences, they are required to expand their knowledge beyond their original fields of study.

Admission Criteria and Program Structure

The program is highly selective, admitting only the most outstanding students with a strong academic record and a demonstrated interest in nanoscience. Admission is based on academic performance and an interview with an interdisciplinary panel of faculty members representing the faculties associated with the program. Once admitted, students can pursue either a Master of Science (MSc) or Doctor of Philosophy (PhD) degree. The acceptance committee, together with the student's advisor tailor a personal study curriculum



Prof. Uri Sivan conferred an Honorary Fellowship on Stephen Seiden in 2024.



(l-r) Dr. Alex Palatnik, postdoc; graduate students Oded Schiller and Noa Konforty- members of Prof. Moti Segev's research group

that balances between the need to be multi-disciplinary, and the needs of the research program. MSc. students are required to complete a research thesis.

Growth and Impact

Since its inception, the Norman Seiden Multidisciplinary Graduate Program has seen remarkable growth. From just six students in its first year, the program now enrolls over 40 MSc and PhD students. To date, the program has graduated more than 200 students, many of whom have gone on to pursue successful careers in academia, industry, and research institutions, positioning Israel as a global leader in nanotechnology research.



(l-r) Prof. Gadi Eisenstein, Stephen Seiden, and Norman Seiden at Technion, 2013.



Leveraging state-of-the-art facilities, technologies and services to power research

INFRASTRUCTURE CENTERS

The extensive network of RBNI infrastructure centers forms the backbone of cutting-edge scientific research and technological advancement across campus.

By fostering interdisciplinary collaboration, these centers support a broad spectrum of scientific and engineering endeavors, ranging from fundamental nanoscience to applied breakthroughs in medicine, electronics, energy, biotechnology, computational research, and materials science. Their strategic role in enabling high-impact research strengthens the institute's leadership in nanotechnology and ensures that faculty, students, and industrial partners can conduct high-quality research that would otherwise be unattainable due to cost or complexity. Cultivating an ecosystem of innovation, these centers not only advance academic excellence but also drive technological and economic development at regional, national, and global levels.



Electron Microscopy Center (EMC)

Technion Center for Electron Microscopy of Soft Matter

Life Sciences and Engineering Infrastructure Center

Surface Characterization Center of the Solid-State Institute

3D-Bioprinting Center for Printing Cells and Biomaterials

Biomechanics and Tissue Engineering Center

Center for Computational Nanoscience and Nanotechnology (TAMNUN)

Focused Ion Beam

Mass Spectroscopy Laboratory

Quantum Matter Research (QMR) Center

Technion Center for Structural Biology (TCSB)

Technion Photovoltaics Laboratory

Biomedical Core Facility

Chemical and Surface Analysis Lab

Russell Berrie Nanoparticles and Nanometric Systems Characterization Center (NNSCC)

Smoler Proteomics Center

Sara and Moshe Zisapel Nanoelectronics Center (MNFU)

2D Center

X-ray Lab

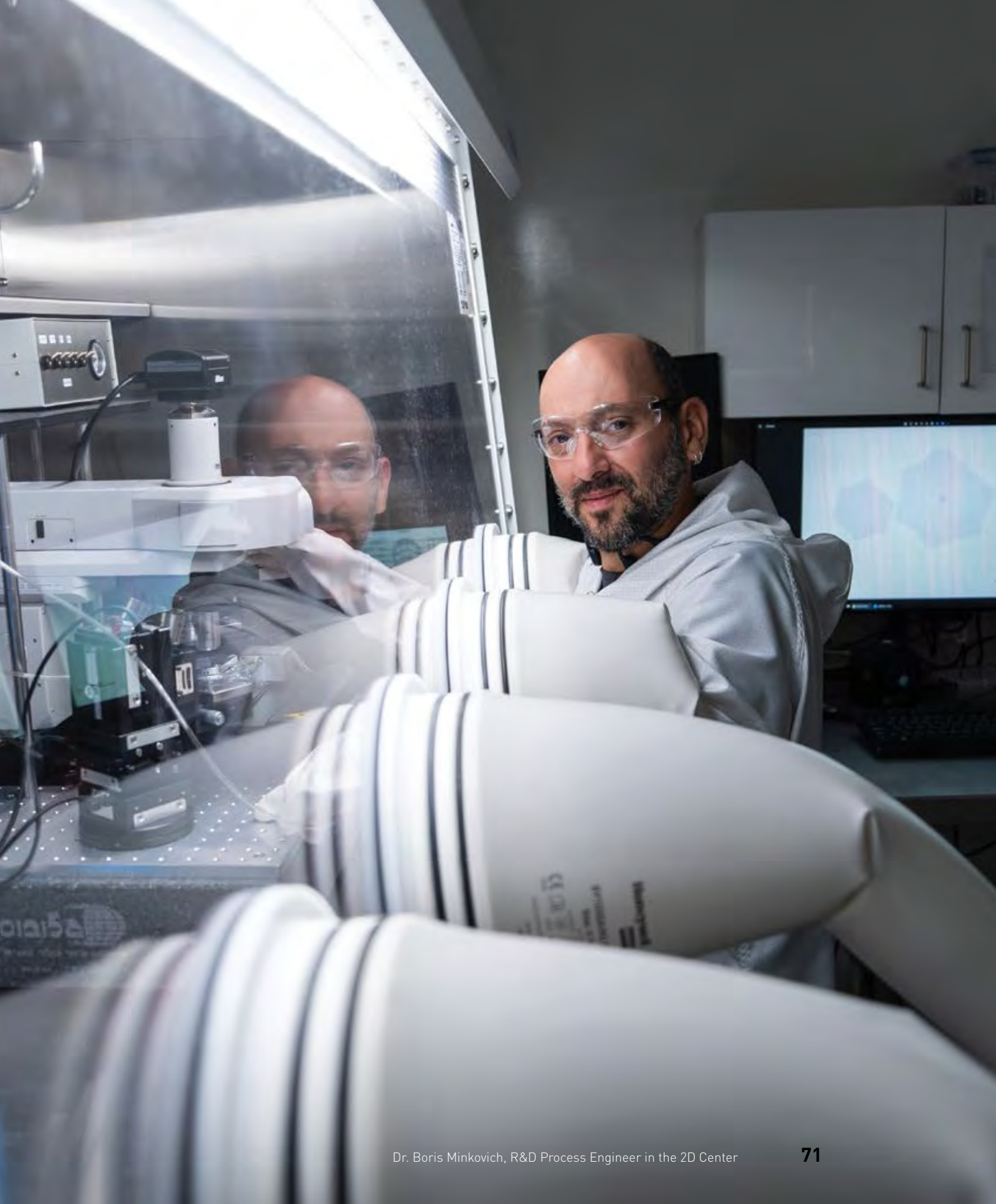


Dr. Assael Cohen, Head of the 2D Center and Associate Research Fellow at the Viterbi Faculty of Electrical and Computer Engineering, is deeply engaged in the pioneering field of 2D materials growth for electrical and optical applications. His research focuses on the controlled synthesis and characterization of 2D materials, exploring their unique electronic and optical properties, and harnessing their potential for a wide range of practical applications within the dynamic landscape of nanotechnology.

2D Center

The Center for Two Dimensional Materials (2D Center), established through a generous donation from the Russell Berrie Foundation, plays a critical role in enhancing the research capabilities of RBNI. This Center is dedicated to the study and development of 2D materials, a rapidly emerging field with significant implications for electronics, photonics, materials science, and nanotechnology. The Center's advanced infrastructure positions Technion at the forefront of 2D materials research, empowering Israel's leading scientists with cutting-edge tools and resources for wafer-scale processing and characterization of 2D materials.





2D Center

Infrastructure

The 2D Center houses advanced tools that support wafer-scale processing and characterization of 2D materials. These materials include graphene, hexagonal boron nitride (hBN), and transition metal dichalcogenides (TMDCs). They are an integral component in the task of developing new electrical and optical devices with unprecedented performance capabilities. The equipment enables researchers to conduct high quality comprehensive growth, fabrication, and characterization, all crucial for producing superior 2D materials and devices.

Key Equipment

✦ Sputtering and SQUID Systems (part of Chemical Vapor Deposition (CVD) systems), specialized CVD Systems for manufacturing various 2D materials, Raman systems for material characterization, TCVD-RF100 system for chemical vapor deposition of TMDCs, laser writing and AFM systems for material analysis and device fabrication, two transfer stations for 3-dimensional heterostructure assembly of 2D materials.

✦ Recent additions include a special pump for the sputtering system, an arbitrary waveform generator for precise control of fabrication, and a Schottky emitter kit. These upgrades have significantly expanded the Center's research capabilities, enabling Technion researchers to achieve world-class results.

Research and Collaboration

Beyond infrastructure, the 2D Center is distinguished by its commitment to fostering knowledge dissemination and collaboration within the scientific community. It offers workshops that cover a variety of topics, from layer transfer techniques to contamination removal and Raman analysis, providing essential skills to both new and experienced users. This collaborative ethos strengthens the Israeli 2D materials community and promotes cross-disciplinary cooperation.



Global Competition and Recruitment

The field of 2D materials is intensely competitive, with research groups worldwide striving for leadership. Before the establishment of the 2D Center, Technion researchers faced significant challenges in competing at the highest levels. With advanced equipment and an enhanced research environment, RBNI members have since gained international recognition in this field. The upgraded facilities also give Technion a strong advantage in attracting top young faculty and PhD candidates eager to pursue cutting-edge research.

Dr. Assael Cohen and Milyutin Yana examine graphene wafers in the 2D Center.

Industrial Impact: 20 years of transformative collaboration

Since its establishment in 2005, RBNI emerged as a national flagship for nanotechnology, fostering strategic collaborations between academia and industry. RBNI was structured not only as a world-class academic institute, but also as a strategic partner to industry, building bridges between fundamental science, advanced engineering, and real-world application. Through hundreds of joint projects, technology transfers, patent filings, and startup ventures, RBNI has significantly bolstered Israel's competitiveness in sectors ranging from semiconductors, photonic technologies, biomedical devices, and quantum materials to drug delivery, advanced manufacturing, defense, and clean energy - underpinning the growth of entire industrial sectors.

With over 250 industry-linked projects, dozens of licensed patents, and a growing alumni network embedded in R&D centers across Israel and abroad, RBNI's impact is measured not only in scientific publications and technological breakthroughs, but also in the ecosystem it helped create—where academia, industry, and government collaborate to advance Israeli innovation.

The research at RBNI has yielded a treasure of intellectual property that benefits the Technion via activities of the Technion business unit, fostering the commercialization of research findings, patent submissions, and technology transfer. Institute faculty members have launched over 50 start-ups, many of which have gone on to secure significant investments, and establish international partnerships.

Catalyzing Innovation through Industry Partnerships

RBNI has maintained long-term collaborations with leading global companies—including Intel, Nvidia, Applied Materials, IBM, and Tower Semiconductor—as well as Israeli key defense industries such as Rafael and Elbit in addition to startups born in its own labs. The Institute's flexible research model and access to advanced characterization and fabrication facilities—notably the Sara and Moshe Zisapel Nanoelectronics Center—have made it a key partner for R&D-intensive companies seeking next-generation technologies.

National Recognition and Strategic Investment

In collaboration with the Israel Innovation Authority, RBNI researchers played a central role in several national technology consortia, helping to define Israel's strategic priorities in photonics, nano-biomedicine, and materials science. Many of these initiatives were led by RBNI faculty, ensuring that Technion's scientific leadership was translated into industrial and national impact.





Tokushima
International
Science Institute

Bridge Between Academia and Industry, Israel and Japan

In 2021, Tokushima International Science Institute (TISI) was established to advance international collaborative research between Tokushima University and Technion, supported by Nichia Corporation, a global leader in Light Emitting Diodes (LEDs) and phosphor technologies. In fact, Nichia is where the blue LEDs and the blue semiconductor lasers were invented. This trilateral partnership is dedicated to joint academic-industrial research, student exchanges, and innovation-driven projects. The collaboration leverages the complementary strengths of the institutions—Technion's excellence in engineering and nanotechnology, TU's advanced research in materials science and medicine, and Nichia's industrial leadership—to foster scientific breakthroughs with real-world applications. The collaboration serves as a "bridge" between Israel and Japan, promoting academic excellence and international understanding. Distinguished Prof. Moti Segev serves as TISI Honorary Distinguished Director.

51 RBNI Startups

NaNose

Develops ultra-sensitive nanotechnology-based sensors capable of detecting chronic diseases and cancers at extremely low concentrations, initiated by Prof. Hossam Haick. Prevention or early diagnosis can dramatically improve outcomes and save lives when illness is unavoidable.

Nurexone

Bases its drug delivery platform on exosomes—nano-sized extracellular vesicles—due to their natural ability to reach inflamed or damaged tissue. By loading exosomes with therapeutic compounds, nanodrugs are generated with natural regenerative properties and therapeutic impact. This venture represents a significant step towards translating Prof. Shulamit Levenberg's research into clinical applications, potentially offering new hope for patients with acute spinal cord injuries.

H2Pro

Pioneers green hydrogen production with a novel, efficient water-splitting technology discovered by leading hydrogen experts Dr. Hen Dotan, Prof. Gideon Grader, and Prof. Avner Rothschild. By lowering costs and increasing safety, H2Pro aims to make hydrogen a viable, large-scale clean energy solution for transportation, industry, and power generation.

NanoGhost

Based on a breakthrough by Prof. Marcelle Machluf in stem-cell-derived nanovesicles, NanoGhosts (NGs) can be loaded with different therapeutics, and delivered directly to tumors. This targeted therapy platform minimizes side effects and maximizes treatment effectiveness in cancer care.



The H2Pro team is reinventing green hydrogen production for economic viability and maximal compatibility with renewables.

The Nano Bible: Our future is where our past is

RBNI's most iconic outreach achievement is the Technion Nano Bible - a powerful symbol of the union between our heritage and cutting-edge science. Since its creation in 2007, the world's smallest Bible has captivated global attention and imagination.

2007 Conceived and created by RBNI founding director Prof. Uri Sivan and Dr. Ohad Zohar (pictured right) as an educational tool, the Nano Bible was designed to fascinate young minds and spark curiosity about the limitless potential of science and technology. The project went viral, gaining global media attention and inspiring audiences worldwide.

Etched onto a silicon chip smaller than a pinhead, the Nano Bible contains all 1.2 million letters of the Hebrew Bible. Using a focused gallium ion beam, researchers engraved the text onto a gold-coated surface only 20 nanometers thick. Visible only at 10,000× magnification, this microscopic marvel showcases the extraordinary potential of nanotechnology.

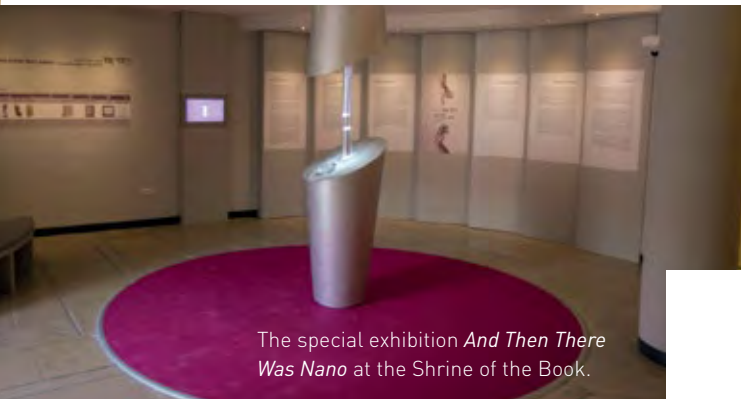




2009 Israeli President Shimon Peres presented the Technion Nano Bible to Pope Benedict XVI at the outset of the Pope's historic pilgrimage to Israel. The unique gift was presented to the Pope in a leather-bound replica of a 13th century Bible, and is today housed in the Vatican.



Dr. Ohad Zohar (l) and Prof. Yitzhak Apeloig (r) show the Nano Bible to Dr. Santiago Calatrava



The special exhibition *And Then There Was Nano* at the Shrine of the Book.



Smithsonian

2015 The Israel Museum marked its 50th anniversary with the special exhibition *And Then There Was Nano* at the Shrine of the Book, where the Technion Nano Bible was displayed alongside the Dead Sea Scrolls—the oldest biblical manuscripts in existence. The exhibition traced the journey of the Book of Books from antiquity to the digital era – from the 2,000-year-old Dead Sea Scrolls to the 21st-century Nano Bible. The exhibition drew over 200,000,000 visitors remaining open almost 3 years.

Smithsonian Secretary David J. Skorton was presented with a Nano Bible by Prof. Uri Sivan at the National Museum of American History in Washington, D.C.

The Nano Bible was inducted into the Smithsonian Libraries collection, and is housed in the Dibner Library of the History of Science and Technology.

2022 As part of the Rakia mission, Israeli astronaut Eytan Stibbe (pictured right) took a copy of the Technion Nano Bible to the International Space Station as a member of the Ax-1 crew, symbolizing the harmony between groundbreaking technology and our heritage.

2024 Technion President Prof. Uri Sivan inaugurated the Nano Bible exhibit at the Jewish Museum in São Paulo - Museu Judaico de São Paulo. The exhibit was initiated by the Friends of Technion in Brazil.



Nano Community

Winter schools, distinguished lectures and workshops



Expanding Global Reach Through Scientific Exchange

As RBNI celebrates two decades of excellence, its commitment to cultivating a global Nanoscience community through scientific exchange and collaboration remains strong. Over the years, RBNI has hosted international winter schools, conferences, symposia, workshops, and a monthly seminar series hosting world-renowned speakers. During the COVID-19 pandemic, the seminar series continued online, maintaining interactive scientific dialogue across borders.

A Premier International Collaboration: Jülich-Aachen-Technion Umbrella Winter Schools

RBNI, in collaboration with RWTH Aachen University and the Jülich Research Center, has played a key role in advancing international scientific exchange through the Jülich-Aachen Umbrella Winter Schools. In September 2024, RBNI proudly resumed their tradition of international forums for scientific exchange between graduate students and faculty, with the Electron Microscopy School at the Jülich Research Center



Julich-Aachen-Technion Umbrella Winter School held in Julich, 2024



in Germany. The school was held within the framework of the 41-year Umbrella Partnership between Technion, RWTH Aachen, and Jülich.

This school brought together an elite group of graduate students from all three institutions for lectures and experimental sessions using some of the most advanced electron microscopy systems in the world. Lectures covered fundamental principles of electron microscopy and applications in fields like materials science, life sciences, and quantum physics.

The Technion delegation was led by RBNI director Prof. Gadi Eisenstein, and faculty members Profs. Yeshayahu (Ishi) Talmon and Ido Kaminer. Social events strengthened the bonds between students and faculty, reinforcing the international Nano community.

Before the pandemic, the flagship RBNI three-institute Winter School took place in December 2018 at Kfar Blum, focusing on Advanced Characterization Methods, welcoming 150 participants, including students from Technion, other Israeli universities, Germany, and beyond. The winter school provided an intensive academic experience in a collaborative environment that fostered learning and international networking. A follow-up Umbrella Winter School was held at the Jülich Research Center in March 2020.

Building Israel's Nano Community

Since the inaugural RBNI Winter School at the Dead Sea in 2008, these programs have become a cornerstone of nanoscience education in Israel, attracting over 140 graduate students and internationally renowned speakers. By 2014, the Schools gained global recognition, strengthening Israel's nanoscience network. Complementary fall symposia offered intensive two-day scientific exchanges for Technion students and faculty. RBNI also hosted major international conferences, including the 2016 Nanophotonics and Advanced Photonic Materials Conference and the 2017 Future of Photonics Conference, bringing together leading researchers and industry experts to share breakthroughs and explore the future of nanophotonics.

Reinhard Frank Symposia

In collaboration with the Center for Nano Photonics at TU Berlin, RBNI organized the Annual Green Photonics Symposium (2014–2016), supported by the Reinhard Frank Foundation, alternately held in Haifa and Berlin, to explore sustainable solutions in photonics and optical technologies. Following this series, the focus shifted to Quantum Science and Engineering, addressing critical challenges in computing and telecommunications, including energy-efficient sustainable solutions for modern data systems. Subsequent symposia were held annually in Würzburg, Haifa, and Munich, continuing this vital international scientific collaboration.

Dream forward. *Dream big...*

The twentieth anniversary of RBNI presents a unique opportunity to rethink its future mission and goals. Given its profound impact on Technion, Israel, and the global research community, RBNI's future challenges and plans must match—and surpass—its influence to date.

Any future vision must begin with the recognition that nanoscience and nanotechnology have matured. RBNI's core strengths are firmly established: world-class nanofabrication infrastructure supported by highly skilled staff; seamless multidisciplinary research across electronics, photonics, physics, chemistry, materials science, mechanics, and the life sciences; and a large community of internationally renowned researchers capable of addressing the most complex scientific challenges.

Building on this foundation, RBNI is positioning itself at the forefront of several research areas with transformative scientific, technological, and societal impact. A central priority is quantum devices for quantum computing, sensing, and communication. Virtually all quantum technologies rely on nanoscale devices requiring extreme precision and reproducibility—capabilities in which RBNI excels.

Another key direction is nanotechnology for human health, encompassing diagnostics and therapeutics. While RBNI already has significant activity in this domain, its long-term vision calls for substantially stronger and broader collaborations with clinicians at the Rappaport Medical Faculty and leading medical centers in Israel and abroad.

RBNI also aims to direct its infrastructure and expertise toward the future of artificial intelligence, fostering close collaborations between physicists, engineers, microscopists, computer scientists, and mathematicians. Neuromorphic information technologies—neurologically inspired electronics enabling revolutionary computing paradigms—represent another strategic focus well aligned with RBNI's strengths.

Additional priorities include unprecedented integration of electronics and nanophotonics within advanced CMOS platforms, novel photonic-based computation schemes, and major contributions to energy and sustainability through strengthened ties with the Grand Technion Energy Program and the Resnick Sustainability Center for Catalysis.

This vision is ambitious and diverse. Careful prioritization will be essential, but RBNI's past demonstrates that no challenge is beyond its reach. The Institute is poised to continue flourishing and advancing goals of critical importance to Technion, Israel, and the world.

Think small.
Dream Big.

RUSSELL BERRIE
INSTITUTE 20YRS
BERRIE NANOTECH

RBNI





Dr. Andrey Wolf, manager of the Photovoltaic Laboratory, stands behind a large dual-chamber sputtering system.



Dr. Larisa Popilevsky , FIB Lab Manager

**And then...
a little bigger.**

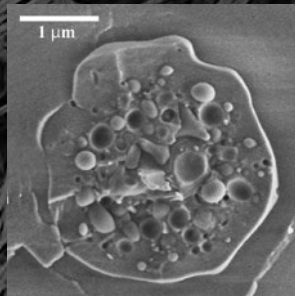


Figure 3: Cryo-SEM image of a healthy human platelet. Talmon Group

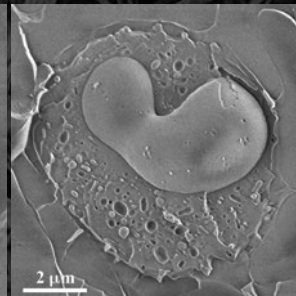


Figure 4: Cryo-SEM image of a healthy human leukocyte. Talmon Group

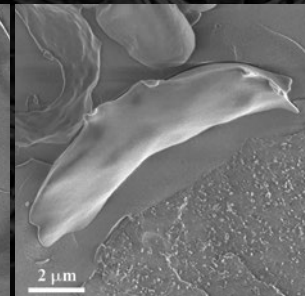


Figure 5: Cryo-SEM image of sickled erythrocyte from a patient with sickle-cell anemia. Talmon Group

*Building a better future from the atom up, that is
nanotechnology. That is what we do here, every day.*

