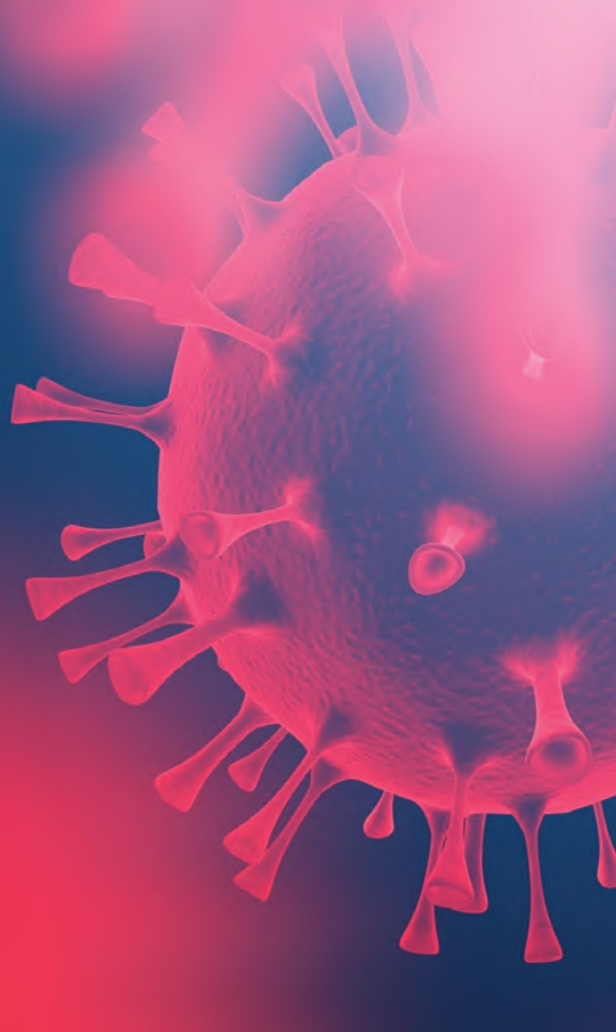
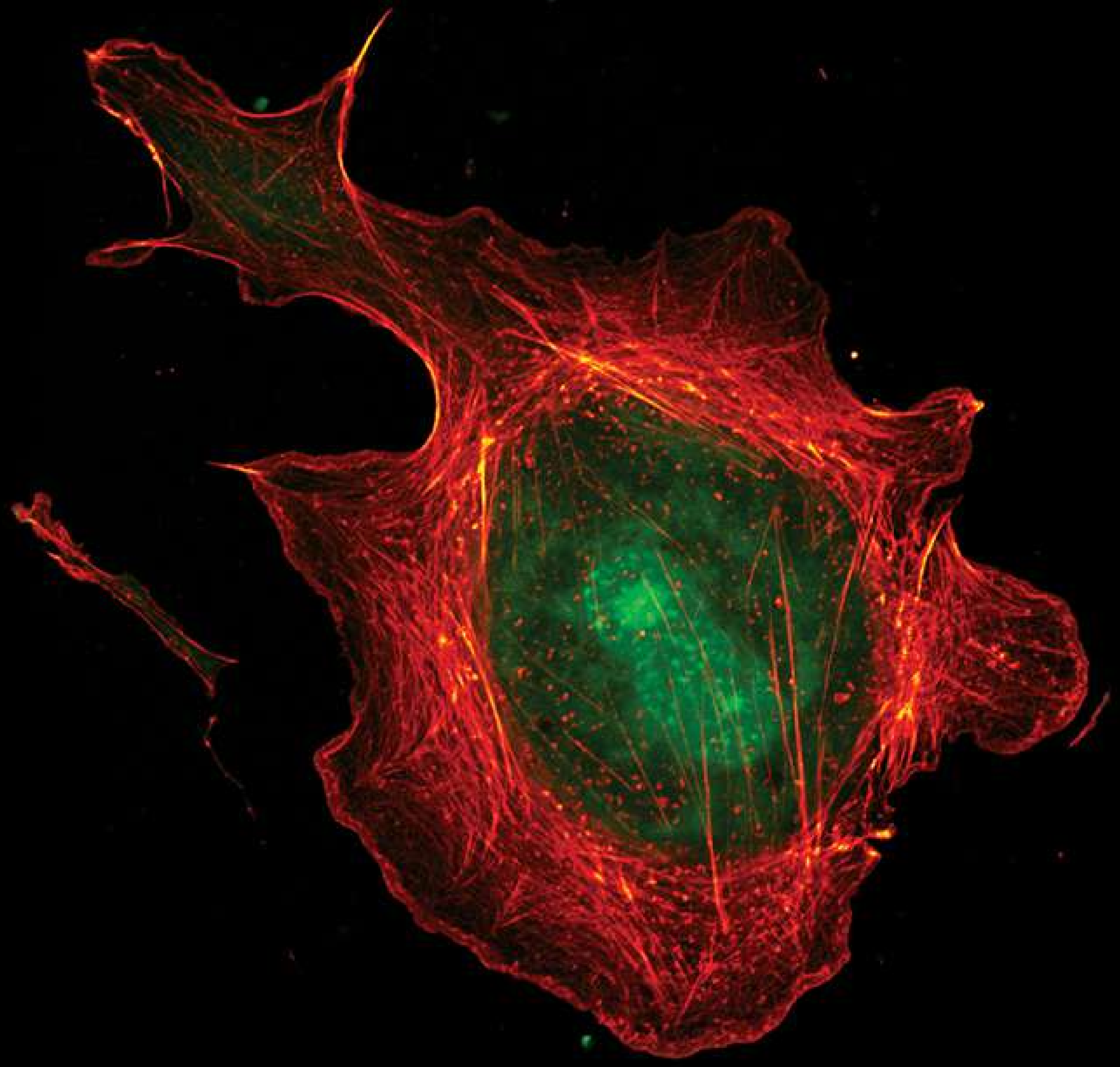
Ilse Katz Institute for Nanoscale Science and Technology

אוניברסיטת בן-גוריון בנגב
Ben-Gurion University of the Negev

Annual Review & Activity Report

2019 2020





Acknowledgments

The impressive progress of the IKI was only possible due to the generous support of our donors:

Ruth Flinkman-Marandy

Henry Weiss Family

Ernest Scheller, Jr. Family

Pullyben Foundation – Yoda Leon & Luna Benoziyo

The Negev Foundation (Robert Equey & Alain Kostenbaum)

Edgar Zantker Charitable Fndt

Max and Rachel Javit

CABGU – Montreal

Dear Friends and Supporters of the Ilse Katz Institute for Nanoscale Science and Technology (IKI)

I take significant pride in the Ilse Katz Institute for Nanoscale Science and Technology (IKI), and the work it does to advance Ben-Gurion University of the Negev in all of the University's undertakings including science, research, education, outreach and technology transfer.

I usually make a humor-based, but serious comment about the IKI's important role in the *"very big world of very small dimensions"*. This year, the entire world is struggling under the crushing weight of the global COVID-19 pandemic. In the past months, I have contemplated the idea of *very small dimensions in a very big world*, but in a very somber way.

Coronavirus is typically in the range of 100 nanometers in size. To view an actual coronavirus you need a powerful microscope based on wavelengths much smaller than light. Most typically scientists use for this purpose *electron microscopes*, instrumentation on hand at the IKI.

This year, not only scientists, doctors, and researchers but also politicians and policy leaders turned to nanoscience for desperately needed scientific solutions for fast and reliable coronavirus detection, air filtration systems, surgical masks, anti-viral agents, disinfectants and identification of vaccine candidates.

I am extremely proud of the IKI researchers, staff and students who have turned to their own work, and their own ingenuity, to see if their research could be harnessed for fighting corona. And of course, I am pleased to report on several promising examples of success in this regard.

In summary, the IKI is currently facing unique challenges at present, as is the entire world! As Director, I can say that I have confidence that the IKI (and BGU) can meet these new and demanding challenges, while still fulfilling its ongoing responsibilities to the researchers, students, and commercial partners of the Institute.

In conclusion, I want to express my appreciation for all of the support we receive from you. Ours is a mutual enterprise; your partnership underpins all that we have accomplished as outlined in the following pages.

I look forward to the day when Covid 19 is far behind us, and we can host you here on campus, opening the doors of the IKI so you, yourselves, can see firsthand all that we undertake at this dynamic and accomplished Institute.

Sincerely yours,

Y. Golan

Yuval Golan, PhD

Professor of Materials Engineering
Director of the Ilse Katz Institute for
Nanoscale Science and Technology

Our Vision

Our *vision for the IKI at BGU* is its recognized status as a center of world-class scientific research and education based on the continuing development of nanotechnologies and their resultant application to central challenges capable of benefitting the Negev, the State of Israel, and society at-large.

Our Mission

The *mission of the IKI* is to promote, enable, and support innovative nanoscale research and education at BGU, which will meet the challenges in our focal areas of interest.

To fulfill this mission, the IKI recruits and supports *leading researchers,* attracts excellent students to this field, establishes and operates *enabling infrastructure* to facilitate cutting-edge research. The IKI promotes *industry-academia interactions* to focus and implement the research it conducts; pursues *development activities* (seminars, workshops, etc.); and lastly, engages in *fundraising* to ensure the budgetary resources necessary for the fulfillment of its mission.

State of the art

Equipment and Instrumentation

For Advanced Science and Technology:

Excellence in science and technology demands innovative equipment and instrumentation. The acquisition of new and updated advanced scientific equipment and instrumentation is a matter of capacity building and strategic investment for the IKI.

The combination of the "best and the brightest" researchers working with the most advanced scientific equipment is the key to achieving new heights (and new sub-nanometer resolutions) for the Ilse Katz Institute.

Listed below are several representative examples of equipment acquisitions in 2019-2020.

Big Success

The Planning and Budgeting Committee (PBC), a sub-committee of the Israeli Council for Higher Education, run a competitive program for institutional scientific equipment. The purpose is to fund large instruments, which serve the needs of a wide range of users. This program is based on "matching," illustrating the need and importance of our donor base. In all cases, the University must provide a minimum of 25% of the purchase cost.

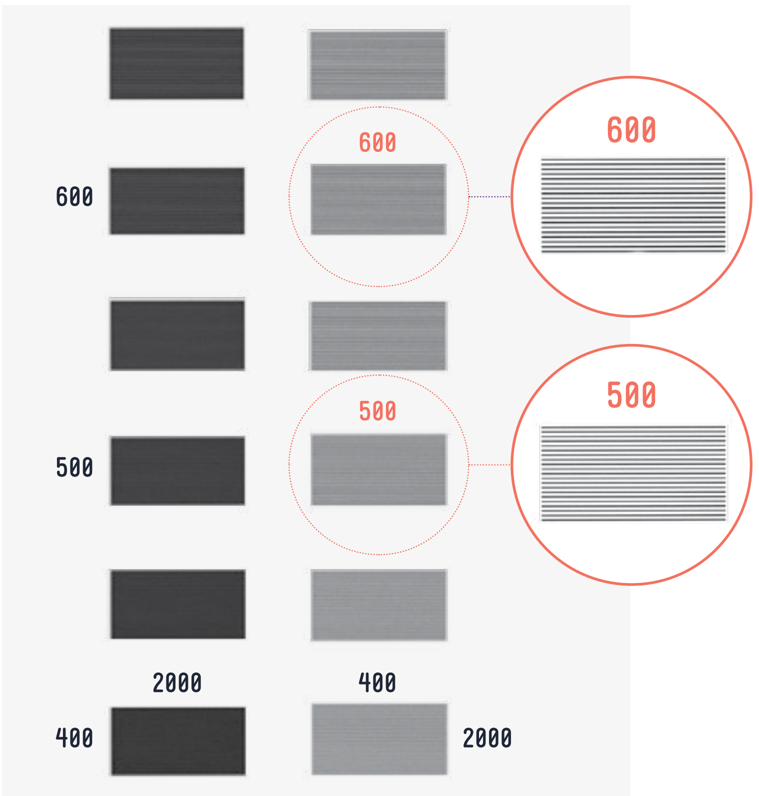
Over the past two years, the Ilse Katz Institute sponsored three winning proposals, illustrating the strength of our research program as viewed through the eyes of the scientific committee of the PBC.

Electron Beam Lithography System

Electron Beam Lithography (EBL) is a nano-patterning method based on scanning of a thin film of sensitive material (resist) with focused electron beam to draw custom 2D and 3D shapes. The beam can be focused to produce shapes sized down to a few nanometers.

Applications are vast and varied, including: optics, nanophotonics, nanobiology, photonics, MEMS/NEMS, solar cells, optical waveguides, microfluidics, etc.

A Raith Electron Beam Lithography system EBPG5150 was installed in the nano-FAB in October, 2020.



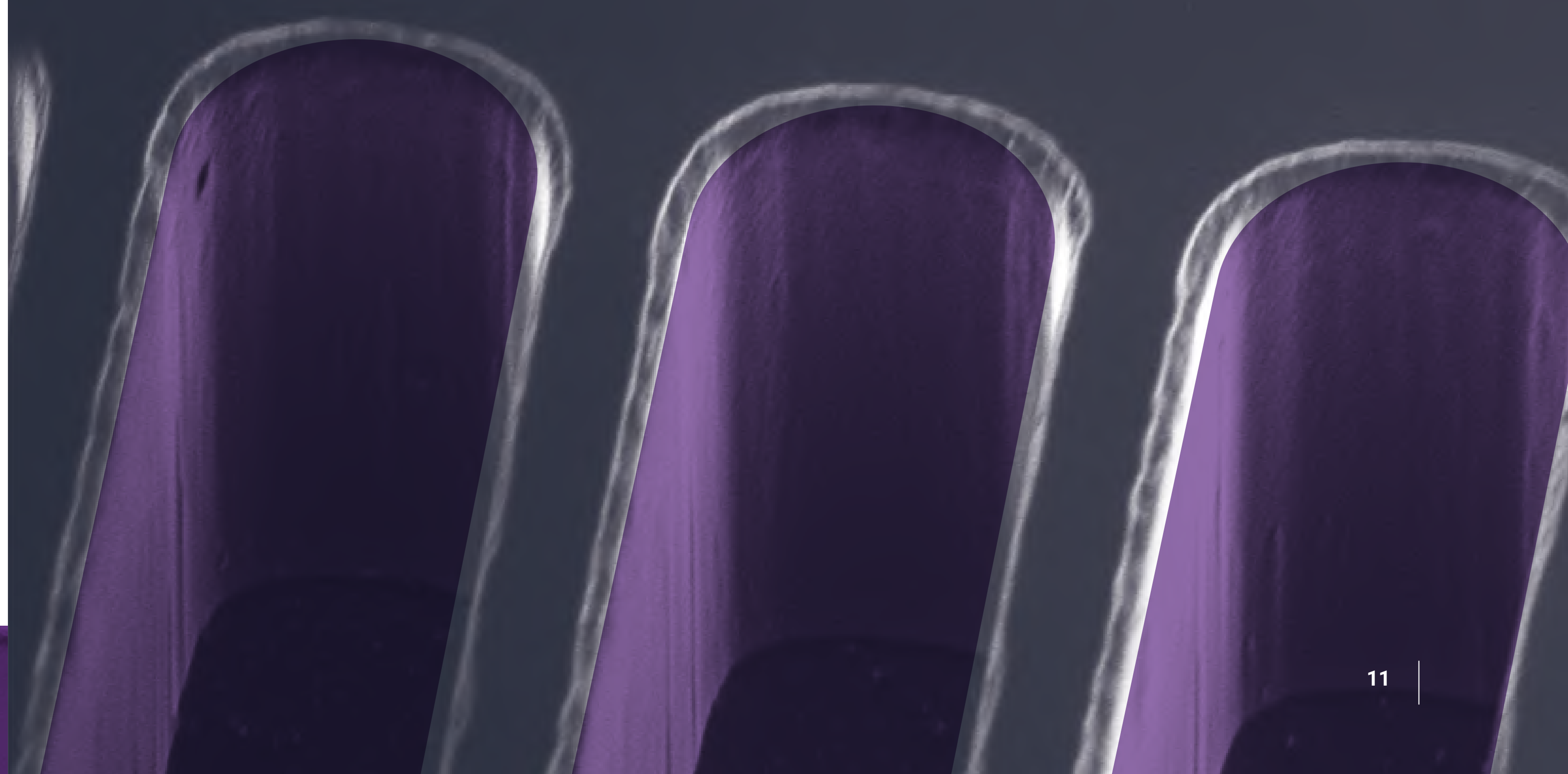
Deep Reactive Ion Etching [DRIE]

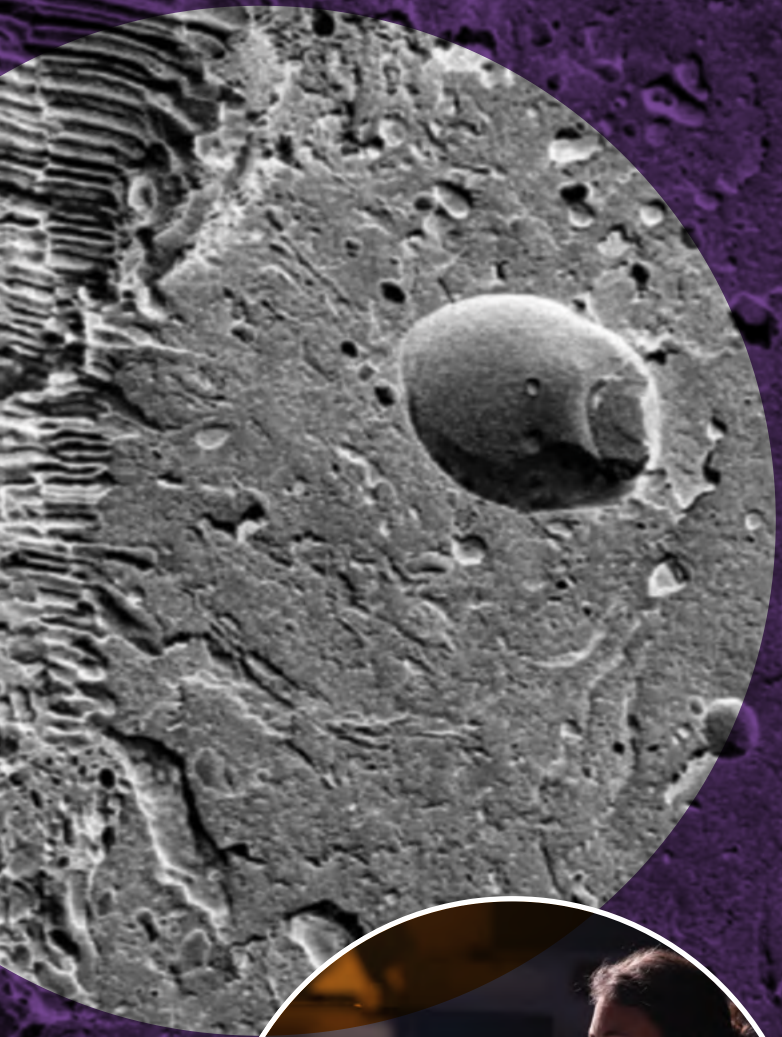
DRIE is a highly anisotropic etch process used to create deep trenches and holes in wafers/substrates, typically with high aspect ratios. Reactive etching process consists of some reactive gas plasma, which etches the substrate while DC voltage bias accelerated the plasma ions in the substrate direction. The forwarded flow of the ions provides anisotropy of the process.

DRIE can be used to fabricate nano-sized vertical and non-vertical structures with high aspect ratio. These structures are crucial for many fields, such as: NEMS/MEMS; solar cells; photonics; optical waveguides; microfluidics, nanobioelectronics; nanoneedles; and porous bio-medical implant materials.

The PlasmaPro 100 Estrelas 100 Etch system and the PLasmaPro 100 Cobra ICP Etch system will compose the machine for the DRIE process. The systems were purchased from Oxford Instruments Plasma Technology UK for our nanofabrication center and the installation is happening those days.

The two systems described above will boost our fabrication capabilities.





Cryo-SEM

Cryogenic Scanning Electron Microscopy (or cryo-SEM) is a state of the art imaging technique, which enables high-resolution imaging of nanometer scale features in fully hydrated samples. In conventional SEM microscopy, biological samples and soft materials must be dehydrated and/or chemically fixed to be imaged at high vacuum. These processes alter the native structure of the materials and lead to the loss of the structural integrity of hydrated samples. Cryo-SEM combines cryo-preservation techniques with high-resolution SEM (HRSEM), enabling biological tissues and wet-materials to be imaged without manipulation in a "close-to-life" state.

Our new HRSEM GeminiSEM 300 – Nano VP Cryo Ready was purchased from ZEISS on December 2019 and installed in August 2020.

A versatile system (as listed below) needed for a complete work-flow, from preparation and preservation of frozen hydrated samples in a native state, to their observation at the HRSEM. The cryo-SEM system comprises 4 parts, which were installed in summer 2020

1. ***A High Pressure Freezing (HPF) – EM ICE (Leica)*** device for rapidly freezing hydrated samples in cryogenic medium.

Cryo-fixation by high-pressure-freezing allows the water in large (up to 200 μm thick) samples to be rapidly vitrified (without the formation of ice-crystals) leading to the almost-instantaneous immobilization of macromolecular components and structures with minimum deformation– critical for preserving the integrity of cellular ultrastructure and soft-condensed matter.

2. ***Freeze-fracture EM ACE900 (Leica) -*** A vacuum chamber equipped with a liquid nitrogen cooled microtome for precise freeze-fracture for uncovering the inner, 'clean' surfaces of samples to be observed in SEM. The instrument is equipped with electron-beam sources for coating samples, for (i) enhancing imaging contrast, (ii) reducing charging effects and (iii) protecting the sample from the electron beam of the SEM. A temperature controlled stage maintains the sample at low temperatures and allows for controlled etching, if required.

3. ***High Vacuum Cryo-Transfer (VCT) system – VCT500 (Leica) -*** for transferring the sample under vacuum and low temperature to the HRSEM.

Additional equipment purchased in 2020 included a Spinning Disk (SD) confocal platform Marians CSU-W System (3i)

which is the gold standard for live cell imaging at high-resolution and high frame rate. The new generation of SD microscopes provides improved resolution (140nm) while maintaining the very high frame rate and low photo-toxicity of SD that is necessary for live cell imaging and for capturing of dynamic events.

This microscope was ordered in April 2020, estimated date for installation April 2021 (may be delayed due to COVID 19 situation) and will be used both for routine and high-performance experiments, and for live-cell imaging applications.

> *The equipment will be operating in designated laboratories at the IKI buildings and administered by the IKI management to the benefit of the entire research community in BGU.*

Meeting the needs of IKI

2021-2022 plans for acquisition

State-of-the-Art X-Ray Photoelectron Spectroscopy (XPS) System

3.3 M ILS secured from vatat out of 4.9 M ILS required

Primary Researchers and Intended Use:

Dr. Eran Edri
Photovoltaics; Artificial photosynthesis

Prof. Menny Shalom
Advanced materials for photo- and electro-catalysis

Prof. Shmuel Hayun
Energy applications and study of defect chemistry

X-ray photoelectron spectroscopy (XPS), also known as electron spectroscopy for chemical analysis (ESCA), is a powerful analytical technique widely used in the surface characterization of materials. XPS spectra are obtained by irradiating a solid surface with an X-ray beam while simultaneously measuring the energy of electrons emitted from the top 1–10 nm of the material being analyzed. XPS is routinely used for qualitative and quantitative surface analyses of the elemental composition and chemical state of the elements within a material. The information XPS provides about surface layers or thin film structures is important for many research applications where surface or thin film composition plays a critical role in performance including: nanomaterials, photovoltaics, catalysis, corrosion, adhesion, electronic devices and packaging, surface treatments, and thin film coatings.

Multi-Purpose Transmission Electron Microscope (TEM) for Materials Research

3.2 M ILS secured from vatat out of 8.3 M ILS required

Primary Researchers and Intended Use:

Prof. Yuval Golan
Chemical epitaxy of semiconductor thin films; surfactant-nanocrystal interactions

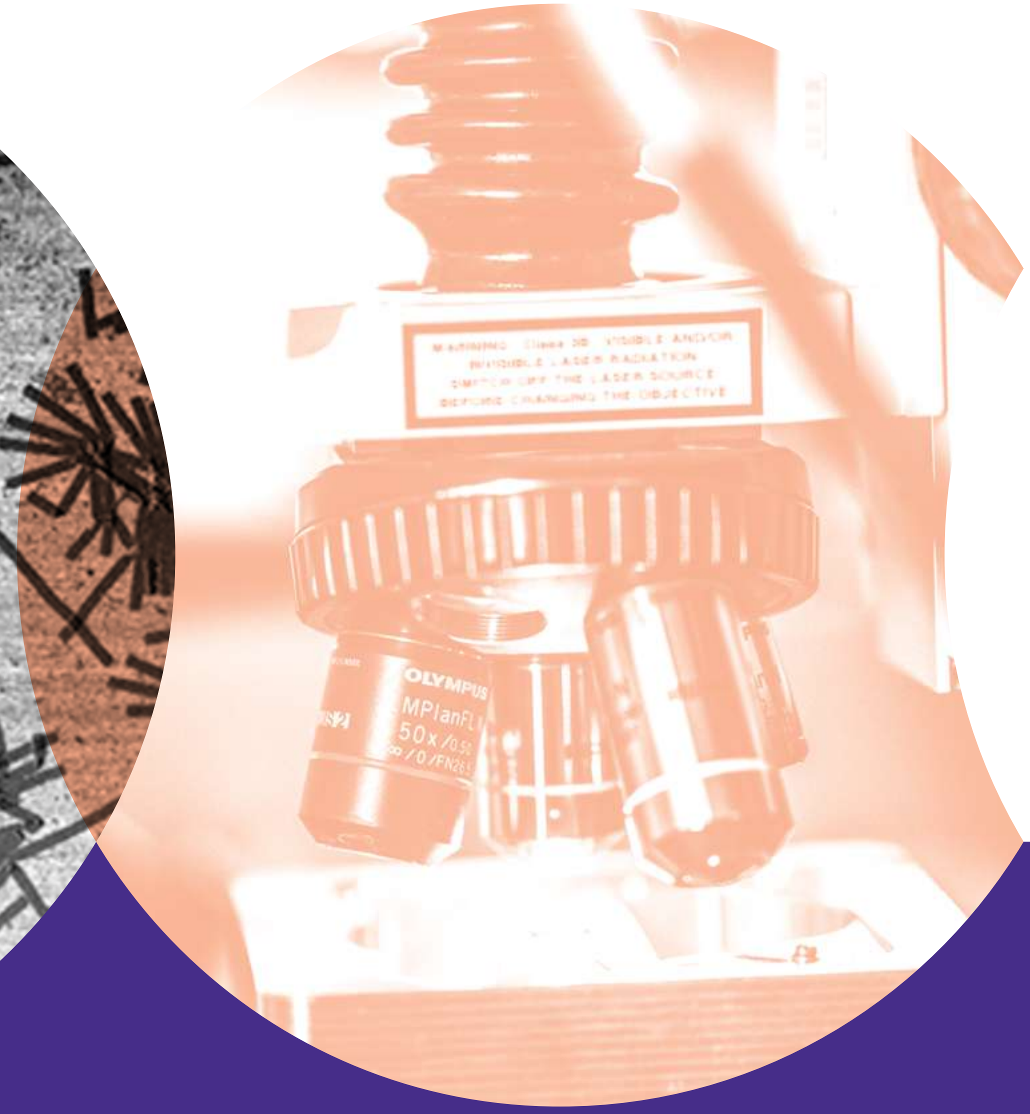
Prof. Louisa Meshi
Electron Crystallography

Prof. Taleb Mokari
Hybrid nanoframes: structural and compositional study in the TEM

Transmission Electron Microscopy (TEM) is a critical enabling tool for materials science. In its analytical configuration, the TEM provides inclusive characterization, including ultra-high resolution imaging, electron diffraction, and spectroscopy techniques, and is a major tool for understanding the structure, morphology, and chemical composition of materials. The requested microscope is designed for fast, precise, and quantitative characterization of nano-materials. The information provided by TEM is crucial for a variety of research applications, and the TEM is expected to have a substantial contribution to the research thrust at BGU, across several disciplines including: Materials Science and Engineering, Electro-optics Engineering, Homeland security, Energy, Water and Environmental studies.

From Molecular Materials to Sensor Arrays

Equipment for the Patterning of Soft Functional Materials and Devices



In recent years, intensive research at BGU has focused on the development of novel functional materials, such as soft organic and bio-organic materials, bio-inspired materials, perovskites, and more. These materials are prospected to leverage the development of novel devices in various areas toward implementation in biomedical, electronic, and optoelectronic applications. However, the development of such applications at BGU is currently limited due to the lack of state-of-the-art fabrication equipment and incompatibility between the material fabrication demands and the "traditional" fabrication infrastructure currently available at the university.

We aim to establish an autonomous center for the development of functional-material based devices. The center will hold state-of-the-art molecular engineering fabrication tools for the deposition, patterning, and printing of devices, including an eight-source, two-chamber thermal evaporator with a maskless aligner; a multi-nozzle high-resolution and high repeatability ink-jet printer; and a state-of-the-art gel- and bio-printer. As such, the center will enable us to study the behavior of soft, bio-inspired, and other functional materials that will be newly developed at BGU, and it will allow the prototyping of new architectures for the assimilation of these materials in advanced applications.
The purchased equipment will be managed as a shared facility, and many researchers at BGU have already expressed their interest in using this equipment.

This center will encompass a combination of sophisticated "traditional" deposition technologies and cutting-edge printing approaches for the fabrication of soft functional material devices.

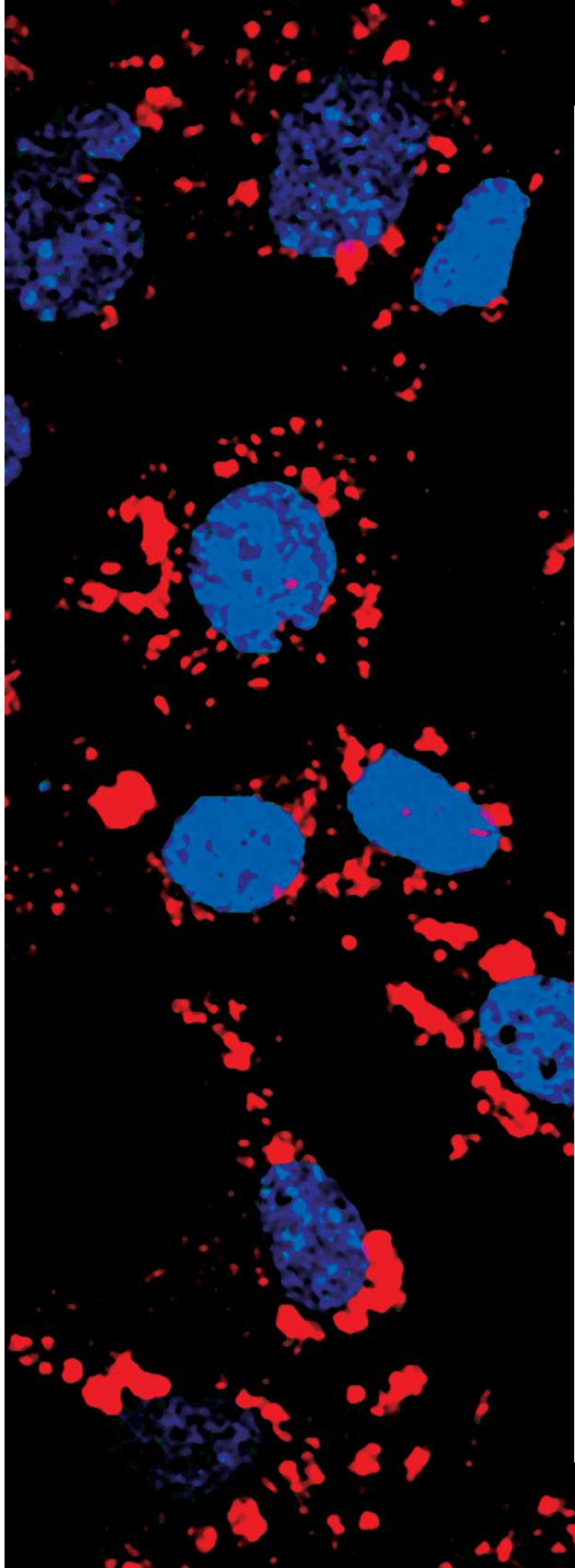
Deposition and patterning – *A multi-source evaporator*, in combination with a *maskless aligner* (allowing direct write), will enable the fabrication of multilayers of soft materials and metals. In addition, it will allow controlling the interface between devices and the surrounding environment, thereby enabling the fabrication of soft material devices for sensing, as well as energy-harvesting, bio-electronic, logic operations and plasmonic applications.

Printing – The properties of novel functional materials facilitate novel fabrication approaches. One of the most exciting advanced approaches is to print the device, instead of "sculpturing" it. We propose purchasing printers that are specifically suited for the fabrication of soft-material devices from a solution or gel phase. Such printers significantly reduce the number of fabrication steps and the amount of material waste. They provide a simple way to fabricate arrays of devices of possibly different materials, leveraging on the inherent diversity of the soft molecularly engineered materials.

Post-printing – For multilayer devices, additional treatments, such as crosslinking and sintering, are often required after the printing stage. These can be easily implemented by using the *maskless aligner* as a localized light source for pattern printing.

Taken together, the proposed center will enable the fabrication of plastic-electronic and bio-electronic devices with supported logical capabilities from soft materials, as well as devices for other applications such as harvesting energy.

Commercialization and Patents



Prof. **Ayelet David**

(Dept. of Clinical Biochemistry and Pharmacology, Faculty of Health Sciences) heads her own research laboratory at BGU - The Drug Targeting and Nanomedicine Laboratory.

Prof. David licensed a patented invention for the development of a tumor vasculature-targeted technology to VAXIL, who will now pursue further development and commercialization.

The technology is protected by a series of worldwide patents:

US08840874

VAXIL
VAXIL BIO THERAPEUTICS

NESS-ZIONA, ISRAEL, Aug. 28, 2019 - Vaxil Bio Ltd. (TSX VENTURE: VXL), a biotech company focusing on innovative immunotherapy treatments for cancer and infectious diseases, announced today that it has entered into an exclusive worldwide license agreement for the development and commercialization of a targeted cancer therapy with BGN Technologies, the technology transfer company of Ben-Gurion University (BGU) of the Negev.

Vaxil sees great promise interest in the P-Esbp polymer-based macromolecule invented by Prof. Ayelet David, together with Prof. Gonen Ashkenasy, head of the Dept. of Chemistry, and Yosi Shamay, their joint Ph.D. student.

The new synthetic P-Esbp polymer developed by BGU targets E-selectin with high affinity for delivering drugs to tumors and metastatic sites. Using primary and metastatic models of cancer, this approach showed promising preclinical therapeutic results, enhancing drug accumulation in tumors, significantly decreasing the rate of tumor growth, and dramatically prolonging the survival of mice with melanoma lung metastases.

Vascular Delivery Systems

Fig. 1 Representative confocal fluorescence images of TNFa-activated (E-selectin expressing), and non-activated human vascular endothelial cells incubated with FITC-labeled P-Esbp. Green, FITC;, Red, Lysosomal tracker; Blue, DAPI for nuclear staining.

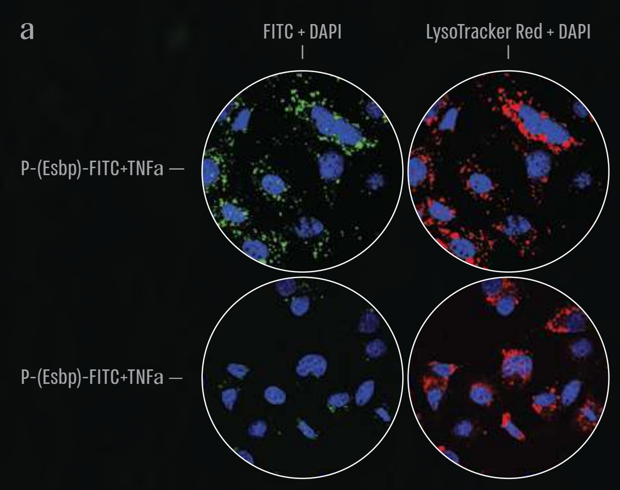
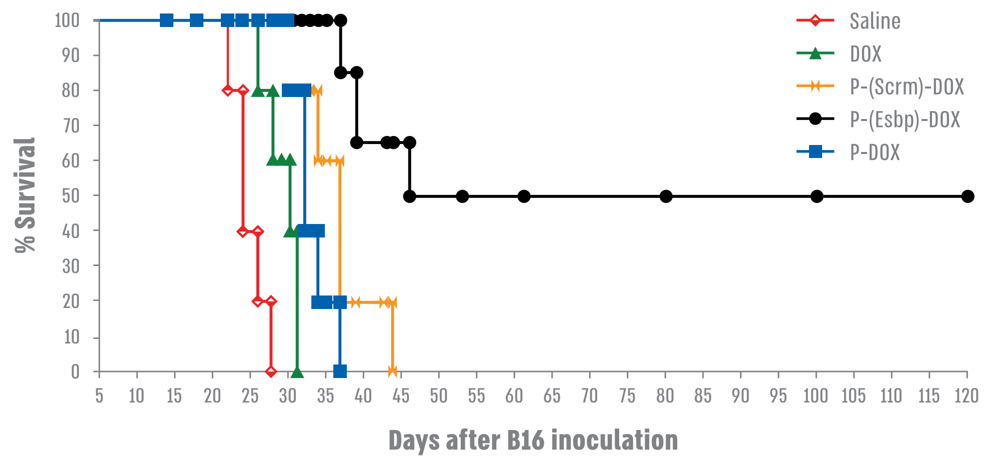
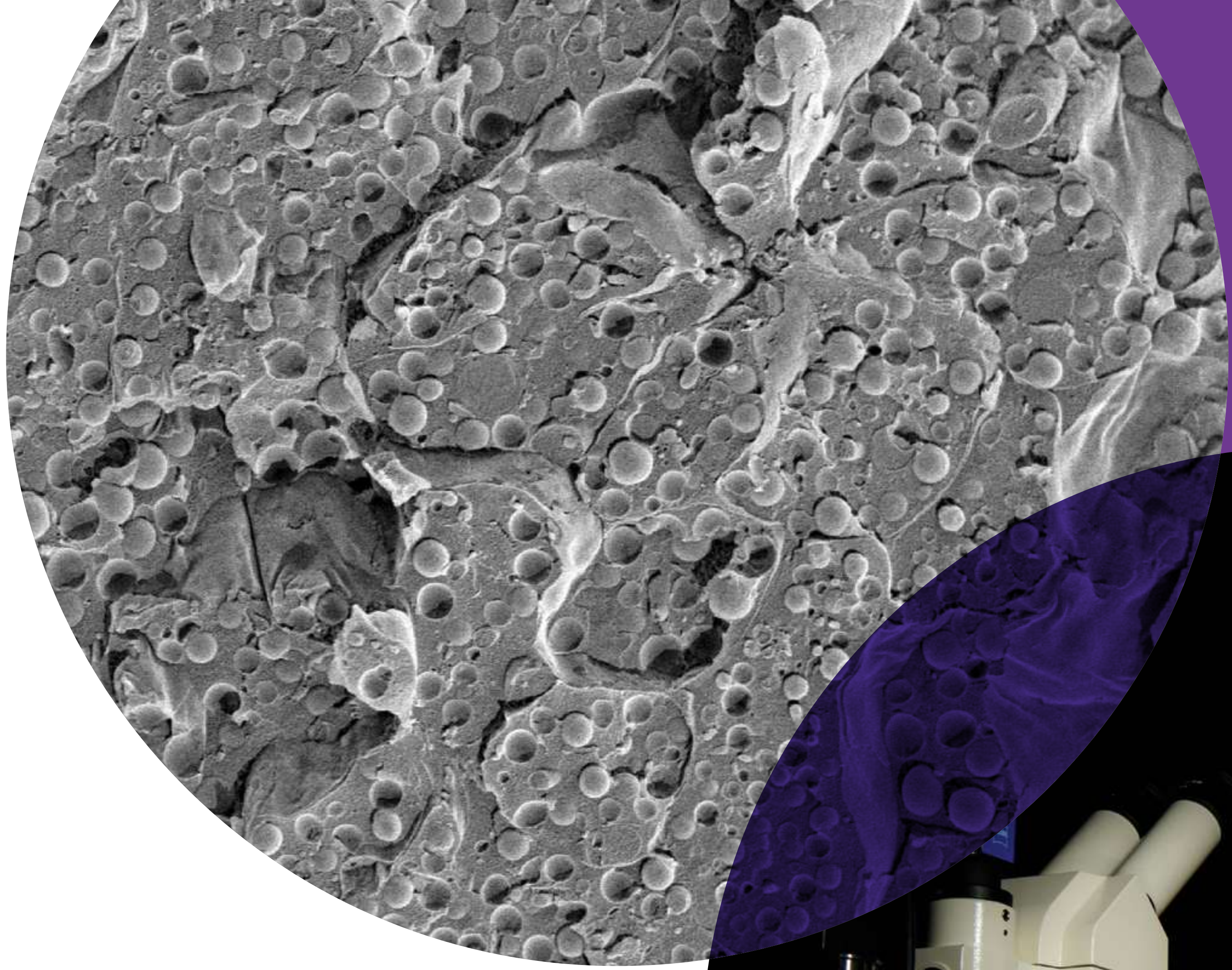


Fig. 2 The anti-tumor activity of P-(Esbp)-DOX in a B16-F10 melanoma pulmonary metastasis model. Mice were treated intravenously on the 7th day after B16-F10 cell inoculation with P-(Esbp)-DOX, P-(Scrm)-DOX or P-DOX with 15 mg/kg DOX equivalent dose, or with free DOX at a dose of 6 mg/kg.



Patent Description
Field of Invention

The innovation describes a new synthetic polymer, designated as P-Esbp, that targets a vascular endothelial cell adhesion molecule (E-selectin) with high affinity and specificity. FITC-labeled P-Esbp facilitated rapid internalization and lysosomal trafficking of the copolymers in human immortalized vascular endothelial cells (IVECs) (Fig.1).
The E-selectin-targeted polymer-drug conjugate (P-(Esbp)-DOX), demonstrated promising therapeutic results in pre-clinical settings, by decreasing the rate of tumor growth, prolonging the survival of treated mice (Fig. 2) and further inhibiting the formation of secondary metastases in different mouse models of metastasis.



Education

Educational activities of the IKI continued as appropriate in 2019-2020, based on well-established precedent. This included nano workshops and seminars, undergraduate and graduate academic programs in nanoscience/nanotechnology, and the active participation of the IKI in the incorporation of nanoscience modules in the curriculum of relevant departments on campus.

Undergraduates

10 (5 in 2019 and 5 in 2020) outstanding students graduated from the IKI's specialized undergraduate nanotechnology program, based on a "double major" program in study, culminating in two distinct B.Sc. degrees: one in Chemistry and one in Chemical Engineering. Separately, 15 (8 in 2019 and 7 in 2020) students began their undergraduate studies – all with the highest credentials.

Doctoral Students

In 2010 the IKI made a decision to adapt to the highly interdisciplinary nature of nanoscience, initiating an interdisciplinary PhD degree program encouraging student mobility across traditional dividing lines.

In 2019-2020, four students graduated from this program:

From IKI to the World

Dr. *Ahiud Morag*

Dr. Morag completed all of his degrees at BGU. He received a “double” bachelor’s degree from the Departments of Chemistry and Chemical Engineering. His master’s degree is from the Dept. of Chemistry, and he then focused on nanotechnology for his doctoral degree (his doctoral research was based on freestanding supercapacitor electrodes). While an advanced research student at the IKI, Ahiud won several prices (e.g., the Shariv Prize in Chemistry and the Efrima Excellence Prize in Nanotechnology).

After finishing his PH.D under the guidance of Prof Raz Jelinek, Ahiud continued for a short PostDoc position in the lab of Prof. Jelinek. He focused on developing ultra-high power density supercapacitors, which can work at high frequencies and exhibit orders of magnitude higher capacitance compared to commercial capacitors. This work resulted in a grant, a patent, and 2 papers.

Since September 2019, Ahiud has been working as a PostDoc at the group of Prof. Xinliang Feng at TU Dresden, Germany.

Dr. *Eliz Amar-Lewis*

Dr. Amar-Lewis completed all of her degrees at BGU. She earned her bachelors and masters degrees from the Dept. of Chemical Engineering and then focused on nanotechnology for her doctoral degree.

Her studies and research spanned and incorporated key elements of nanomaterials, biotechnology, cell culture, drug delivery (at the nanoscale) and cancer therapy.

She was recruited by Triox Nano Ltd. - an innovative biotech company developing programmable biologic nanocarriers that are capable of accurately delivering payloads to their target.

The novel drug delivery platform code name is **S.M.A.R.T.** “Stimuli Multi Adjusted Responsive Technology” and is based on the unique combination of mesoporous nanoparticles (MSNP) and DNA molecular machines (DNA MM). S.M.A.R.T. creates the basis for programmable nano-machinery capable of carrying different payloads (active pharmaceutical ingredients -or- APIs) to specific tissue targets. S.M.A.R.T.’s flexibility creates possibilities for intelligent, nanoscale, computerized DNA molecular machines to be able to sense combinations of environmental variables, (e.g. ions, metabolites, and receptors) and unload active payloads (e.g. chemotherapy, siRNA, or isotopes). The practical result is that much smaller doses (with greatly reduced side effects), can be exploited for precision delivery of the API to target tissue.

Dr. Eliz Amar-Lewis will focus her time and energies on triple-negative breast cancer, an aggressive form of breast cancer for which no targeted therapy exists. Preliminary animal models show that S.M.A.R.T. has 20 times higher efficacy and safety compared to the gold standard. Dr. Eliz Amar-Lewis’ position at Triox Nano includes design and execution of experiments along with taking new directions of the study in order to implement the technology.

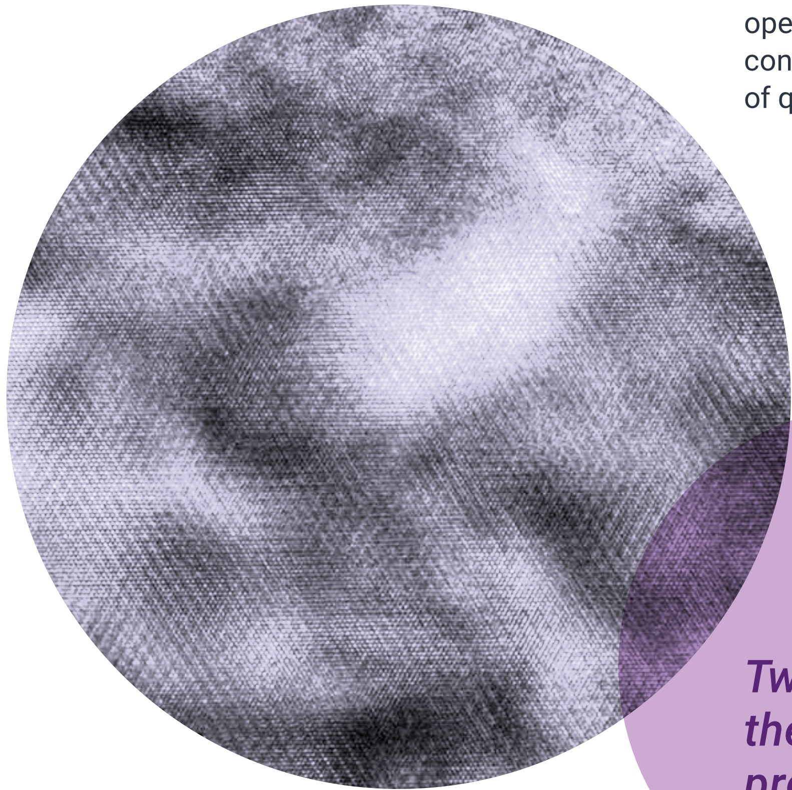
Dr. *Ifat Cohen-Erez*

Dr. Cohen-Erez completed all of her degrees at BGU. She earned her bachelors and masters degrees from the Dept. of Biotechnology Engineering and then focused on nanotechnology for her doctoral degree in the lab. of Prof. Hanna Rapaport. The topic of her research was "Peptide based nanoparticles for intracellular delivery to mitochondria".

Dr. Cohen-Erez chose to remain in academia and became a staff research engineer at the Avram and Stella Goldstein Goren Department of Biotechnology Engineering at BGU. She is now managing two research laboratories, one focuses on peptides and biomaterials engineering and the other on cancer and stem cells.

Dr. *Elinor Zerah-Harush*

Dr. Cohen-Erez completed all of her degrees at BGU. She earned her bachelors and masters degrees from the Dept. of Chemistry and then focused on nanotechnology for her doctoral degree in the lab. of Prof. Yonatan Dubi. After completing her thesis Elinor has started a short-term post Doc at Prof. Yonatan Dubi lab. She is working on two papers that are currently under review process in Science advances and in the Journal of physical chemistry letters. Her latest manuscript (currently under review in “science advances” journal) basically answers one of the central questions in the field of quantum biology: does quantum coherence contribute to photosynthetic efficiency? In addition, she is working on a new project related to a novel architecture of quantum neural networks. The goal of this project is to lay the foundations and to examine the feasibility of using transport of quantum particles on a network to perform tasks such as classification, combining of network optimization algorithms and natural propagation of quantum particles in open systems. During her post Doc, she is considering a few post Doc options in the field of quantum information.



Two new students started their doctoral research in the program in 2019-2020.

Specialized Training and Customized Exposure

for Students in Selected Areas

1

The Dual Beam FIB was purchased at the end of 2017 and installed during 2018. In 2019 a noteworthy effort was done in broadening the knowledge and skillfulness of the team and users on the instrument. A seminar, followed by a demo, was conducted by Thermo Fisher Scientific Israel and IKI specialists: "Dual Beam at BGU, new capabilities for 3D Nano-scale Materials Characterization".

2

BGU Nanofabrication Center continued to carry out a variety of courses to the benefit of the BGU academic community. Classes from introductory to advanced, each uniquely specialized to demonstrate nanofabrication techniques for the students' specific fields of study:

- Micro-electro-mechanical systems (MEMS) devices seminar for mechanical engineering students
- Nano-applications in energy and environmental engineering for desert studies M.Sc. students
- Chemical vapor deposition (CVD) laboratory course for materials engineering students
- Bio-sensing seminar for bio-medical engineering students
- Hands-on introduction to cleanroom processes for electrical engineering and biotechnology engineering students.

3

4th year undergraduate students in materials engineering participated in an advanced teaching lab on nano-ceramics using advanced scientific techniques at the IKI, including electron microscopy, x-ray diffraction and x-ray fluorescence spectroscopy.

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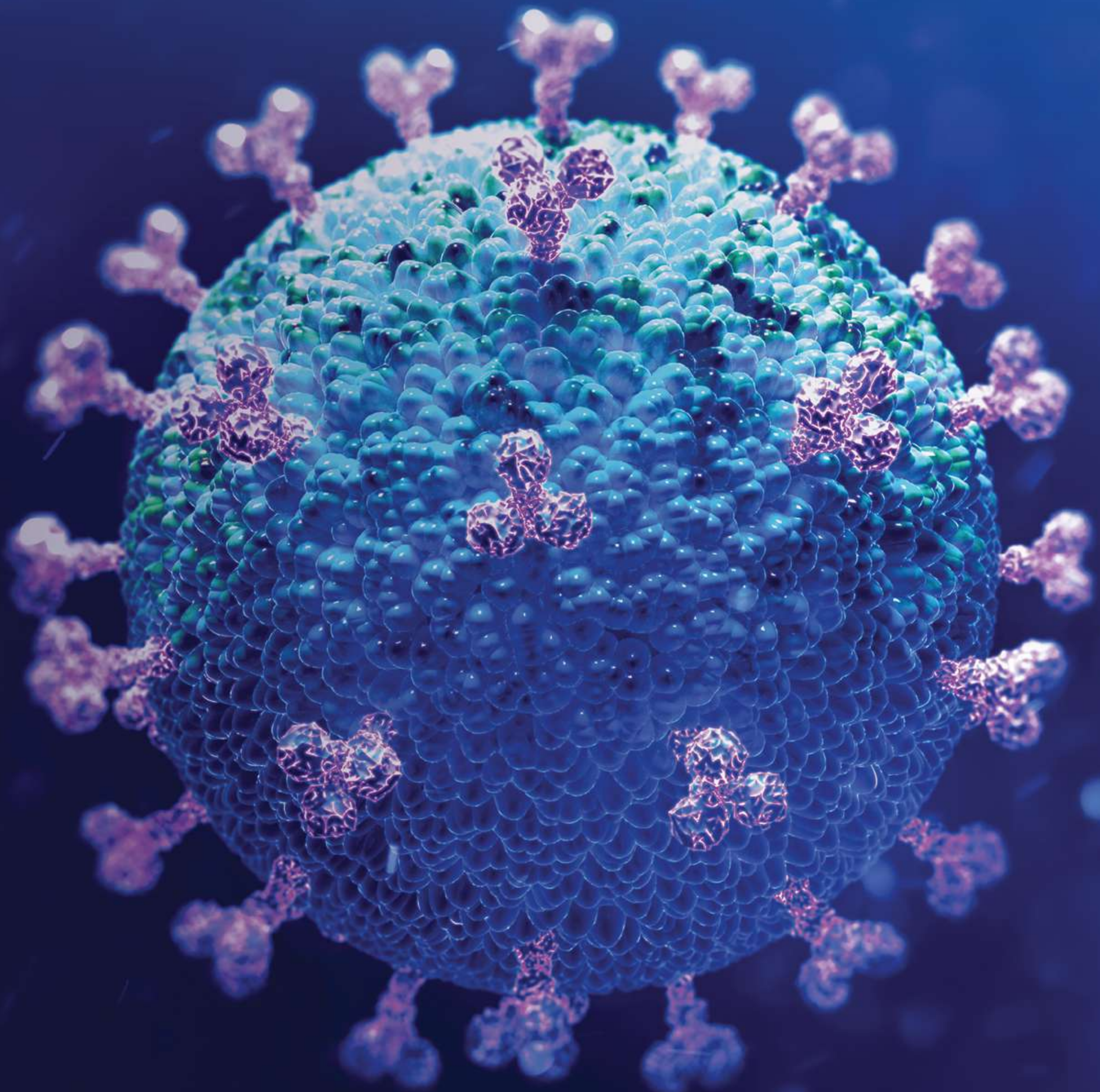
Coronavirus and Nano-Research



Recyclable Sunlight-Sterilized Facemasks

Nanoporous membranes comprising carbon dots (C-dots) and poly(vinylidene fluoride) (PVDF)

Lead Researchers:

Raz Jelinek, Department of Chemistry, and Christopher J. Arnusch, Dept. of Desalination & Water Treatment and Researcher at the IKI.

Goal:

Development of reusable, environmentally friendly facemasks which can effectively block viral transmission.

Description:

Facemasks are considered the most effective means for preventing infection and spread of viral particles. In particular, the coronavirus (COVID-19) pandemic underscores the urgent need for developing recyclable facemasks due to the considerable environmental damage and health risks imposed by disposable masks and respirators. We demonstrate synthesis of nanoporous membranes comprising carbon dots (C-dots) and poly(vinylidene fluoride) (PVDF), and demonstrate their potential use for recyclable, self-sterilized facemasks. Notably, the composite C-dot-PVDF films exhibit hydrophobic surface which prevents moisture accumulation and a compact nanopore network which allows both breathability as well as effective filtration of particles above 100 nm in diameter. Particularly important, self-sterilization occurs upon short solar irradiation of the membrane, as the embedded C-dots efficiently absorb visible light, concurrently giving rise to elevated temperatures through heat dissipation.

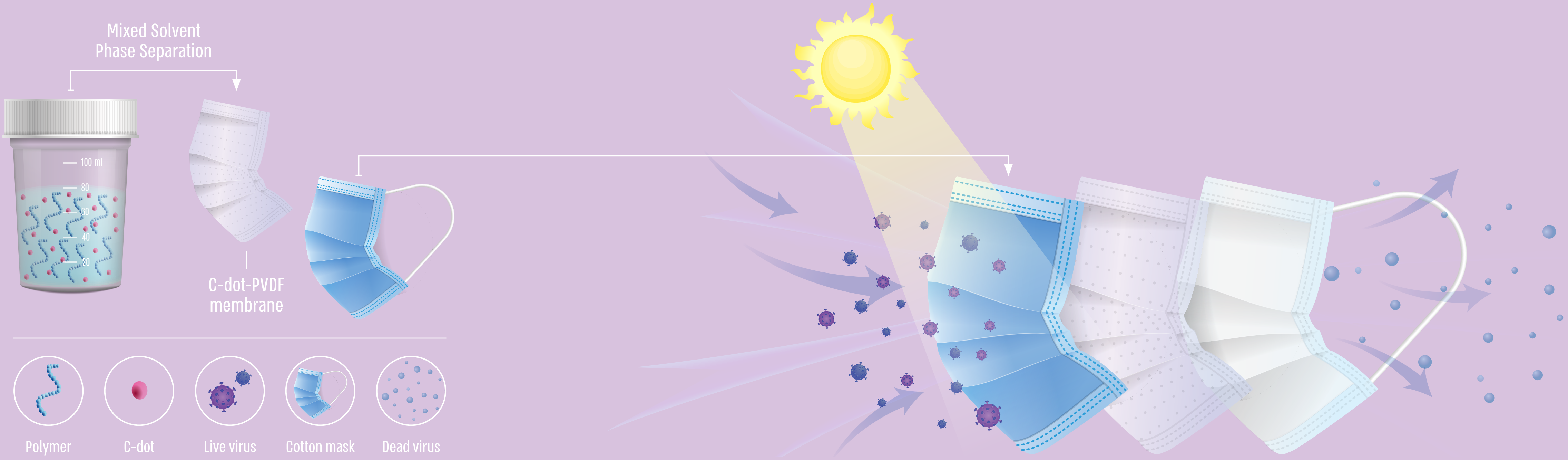
Milestones Achieved:

This work presents the development of a new self-sterilized facemask membrane technology capable of effectively blocking and eliminating airborne biological nanoparticulates, specifically viruses such as COVID-19 and microorganisms. The nanoporous barrier comprises C-dot-PVDF membrane synthesized from readily available and inexpensive building blocks through a simple mixed solvent phase separation method. The new C-dot-PVDF films exhibit important properties required for potetial use as recyclable facemasks, including effective nanoparticle blocking, hydrophobicity, and self-sterlization. Specifically, the free-standing membrane films were hydrophobic and exhibited excellent filtration capabilities for nanoparticles in the size range of COVID-19 viral particles while attaining good breathability. Importantly, solar-induced self-sterilization could be accomplished due to the highly effective sunlight absorbance by the embedded C-dots and concomitant heat dissipation.

The C-dot-PVDF membrane technology exhibits important advantages in comparison to existing or proposed recyclable facemask systems. The uniqueness of the C-dot-PVDF system is due to integrating the distinct properties of the individual constituents – the nanoporosity and hydrophobicity of the polymer framework and photothermal properties of the C-dots.

Project Potential:

Integration of the C-dot-PVDF system with cotton cloths, furnishing commercially available recyclable anti-COVID-19 facemasks. Future expansion of the technology towards microorganism, viral, and nanoparticle filtration systems would be also feasible.



Construction of the nanoporous C-dot-PVDF sunlight-mediated self-sterilizing anti-Covid-19 facemask. The C-dots and PVDF are initially dispersed in a DMF/n-octane mixture. A free-standing nanoporous film is formed through mixed solvent phase separation. Sunlight is absorbed by the film-embedded C-dots, resulting in heat dissipation which can be utilized for concomitant destruction of viral particles.

COVID-19 at the Interface of Nano and Preventive Medicine

Anti-Coronavirus Surface Coating ***Based on Nanomaterials***

Lead Researchers:

Angel Porgador, Shraga Segal Dept. of Microbiology, Immunology and Genetics; Mark Schvartzman, Dept. of Materials Engineering and Researcher at the IKI.

Goal:

The researchers are developing novel surface coatings that will have a long-term effect, and contain nanoparticles of safe metal ions and polymers with anti-viral and anti-microbial activity.

Description:

The coronavirus is transmitted between people mainly via respiratory droplets, but it is known that the virus remains stable on various surfaces for days. Since the virus can spread through contaminated surfaces, it is important to be able to sterilize surfaces with high contamination potential, such as doorknobs, elevator buttons or handrails in public areas in general, and in hospitals and clinics in particular. However, current disinfectants provide only a temporary measure until the next exposure to the virus.

Innovation Aspects:

Certain metals can be lethal, even in small quantities, for viruses and bacteria and are not poisonous to humans. Findings show that surfaces coated with copper nanoparticles strongly block infection of the cells by the virus. These ongoing experiments show a huge potential for copper ions in preventing surface-mediated infection with SARS-CoV-2.

Milestones Achieved:

Based on their findings thus far, the researchers are developing anti-viral coatings that can be painted or sprayed on surfaces. The coatings are based on polymers, which are the starting materials of plastics and paints, and contain nanoparticles of copper and other metals. The nanoparticles embedded in the polymer will enable controlled release of metal ions onto the coated surface. Studies show that these ions have a strong anti-viral effect, which can eradicate virus particles that adhere to the surface. Because the release of ions is extremely slow, the coating can be effective for a long period of time – weeks and even months, and it will reduce the infectivity of the virus particles by more than 10-fold.

Read more: THE JERUSALEM POST

SELF-STERILIZING AIRFILTERS:

Anti-Microbial Laser-Induced Graphene (LIG) With Electrical Charges

Lead Researcher:

Christopher Arnusch, Dept. of Desalination & Water Treatment and Researcher at the IKI.

Goal:

Converting advanced anti-bacterial water filtration for use against COVID-19.

Innovation Aspects: The use of laser-induced graphene (LIG), together with electrical charges.

Description:

Expertise gained in LIG as an anti-bacterial surface in water filtration and water purification systems will be applied to a special air filter for use in either personal face masks or full-scale air filtration systems. The use of laser-induced graphene, together with low electrical charges will result in a filter material with extraordinary filtration properties – with a goal of deactivating 99.9% of infectious particles.

Milestones Achieved:

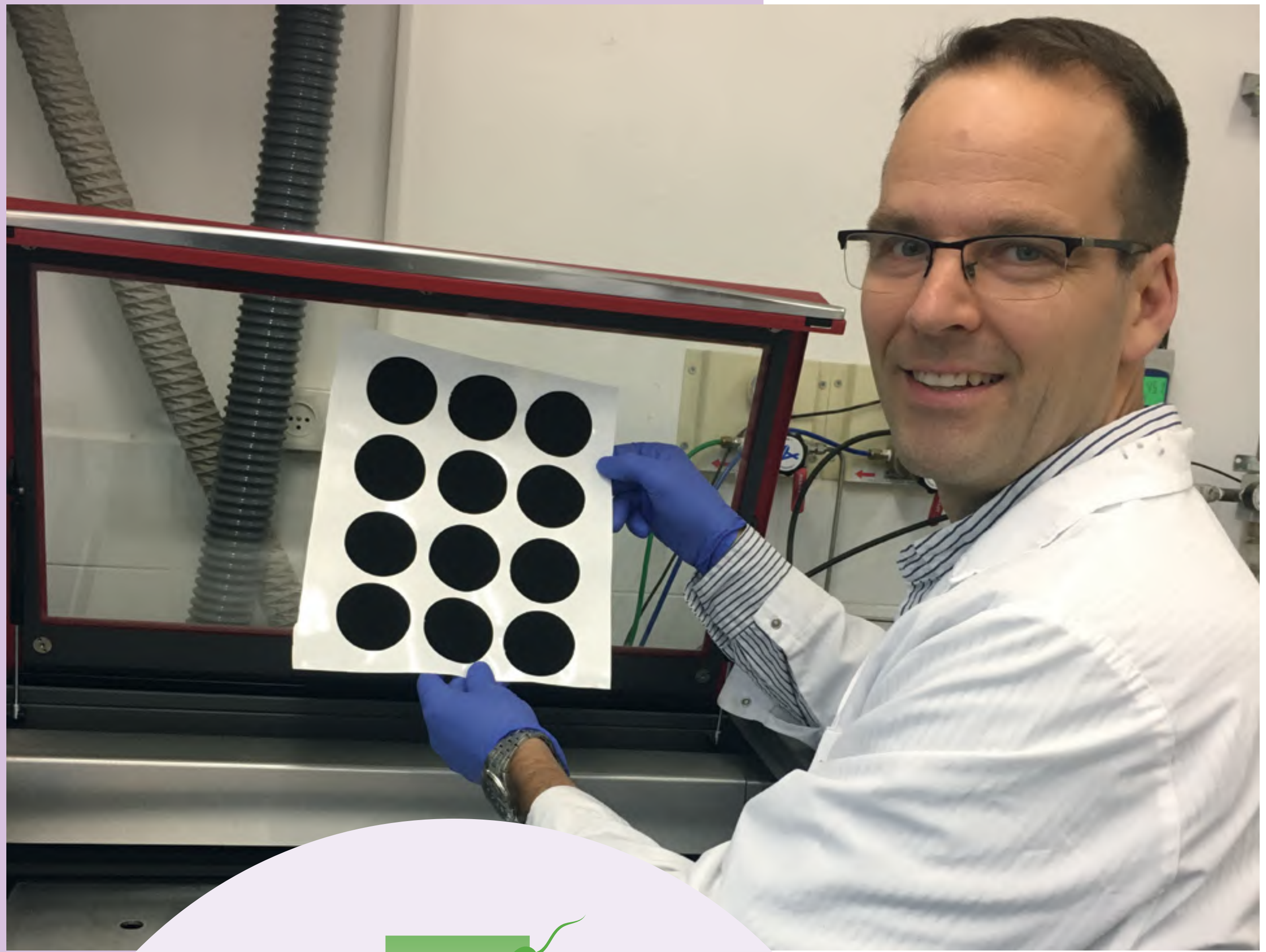
An air simulation system has been established in the research laboratory, with preliminary testing evidencing strong microbial killing effects for electrified LIG coatings. The Israeli Ministry of Science and Technology (MOST) provided partial support for further experimentation.

Project Potential:

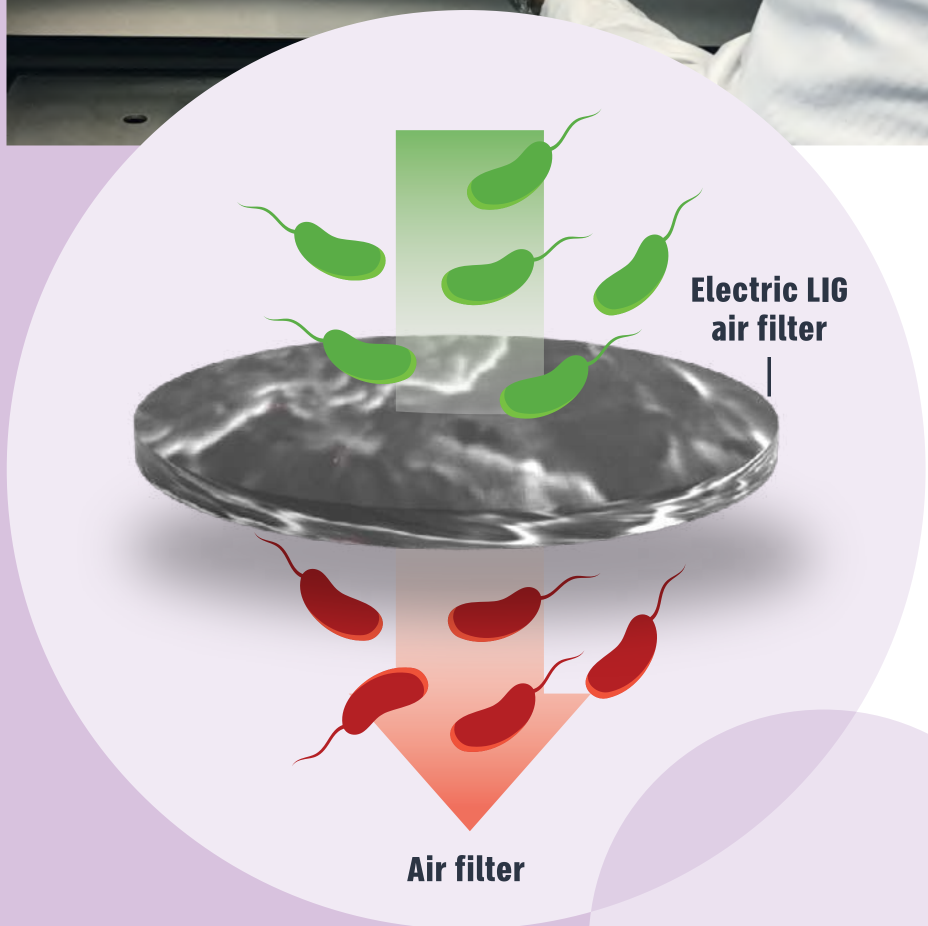
A new air filter material capable of deactivating 99.9% of infectious particles which can then be incorporated into personal face masks or ventilations systems for buildings and vehicles.

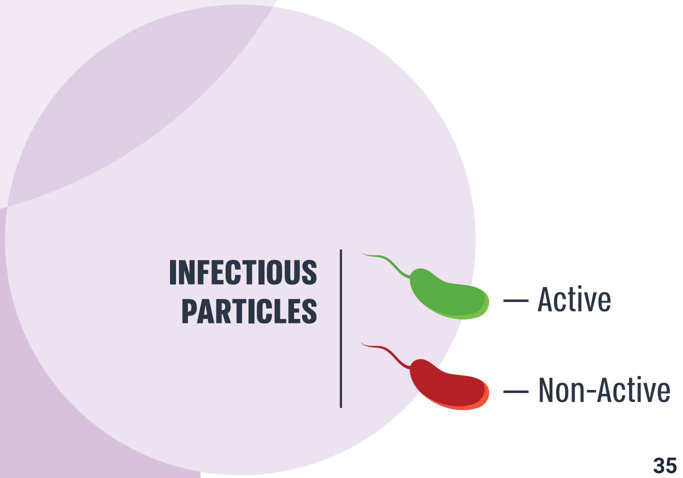
Read more:

ISRAEL21c



Laser-induced graphene (black circles) fabricated on a polyethersulfone water treatment membrane support





Geospatial Distribution of Corona Virome *

Monitoring Traces of COVID-19 in Urban Sewage Systems

** **Virome** refers to the assemblage of viruses characterized by their viral nuclei acids and associated with a particular ecosystem*

Read more:

THE JERUSALEM POST

Newsweek

Listen to learn more:

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Researchers:

Ariel Kushmaro and Karin Yaniv, Avram and Stella Goldstein-Goren Department of Biotechnology Engineering; Yakir Berchenko, Department of Industrial Engineering and Management; Eran Friedlander, the Technionand and Itai Bar-Or, Ministry of Health.

Goal:

To survey and trac disease spread in different geographic regions by examining wastewater and sewage for traces of genetic material of SARS-CoV-2 the causative agent of COVID-19. This protocol can be used to verify virus presence, its elimination following vaccination or cure, or alternatively, to substantiate the need for additional containment efforts.

Innovation Aspects:

Using wastewater and sewage, instead of patient reports, for an ongoing and constant population-based surveillance and tracking of pathogen transmission dynamics.

Description:

Waterborne pathogens, including viruses, bacteria and protozoa are routinely shed into the urban water cycle via leaking sewers, urban runoff, agricultural runoff, and wastewater discharges. Recent studies found high concentrations of virus particles in wastewater, indicating that this may provide an important environmental monitoring tool for assessing pathogen dispersal in the community.

The high concentration of virus particles in wastewater treatment plants (WWTP), allowed us to apply existing technologies and methodologies in order to follow the novel coronavirus SARS-CoV-2 in wastewater from selected locations in Israel.

Milestones Achieved:

This method was validated using sewage samples collected from a COVID-19 isolation facility in Tel Aviv. The preliminary study provides a proof-of-concept for the ability of this technology to detect SARS-CoV-2 RNA in sewage. Results showed a linear correlation between case reports and the number of viral particles in the sewage indicating that this methodology may be pivotal for large scale surveillance from different localities in Israel, including from the Tel Aviv metropolis.

Project Potential:

This technology provides an early warning system capable of detecting viral traces prior to a spike in cases once people fall ill. Importantly this early warning can provide public health officials with means to combat the "silent circulation" of COVID-19 via asymptomatic carriers.

Saliva-based Detection for COVID-19

(An Important Screening Strategy and Triage Tool)

Lead Researcher:

Robert Marks, Avram and Stella Goldstein-Goren Dept. of Biotechnology Engineering and IKI Researcher.

Goal:

An initial screening system designed for large-scale testing and detection of COVID-19 across large groups of people.

Innovation Aspects:

Saliva-based testing and the use of synthetic peptides for the future production of monoclonal antibodies.

Description:

At peak moments in the trajectory of the virus, testing volume increases and backlog results. Initial research indicates the high probability of COVID-19 virions in human saliva. This project is designed to result in a convenient, quick, and non-invasive means of diagnostic testing. The lower accuracy of saliva-based testing is recognized, but potential for large-scale use results in efficacy as an initial screening strategy and important triage tool.

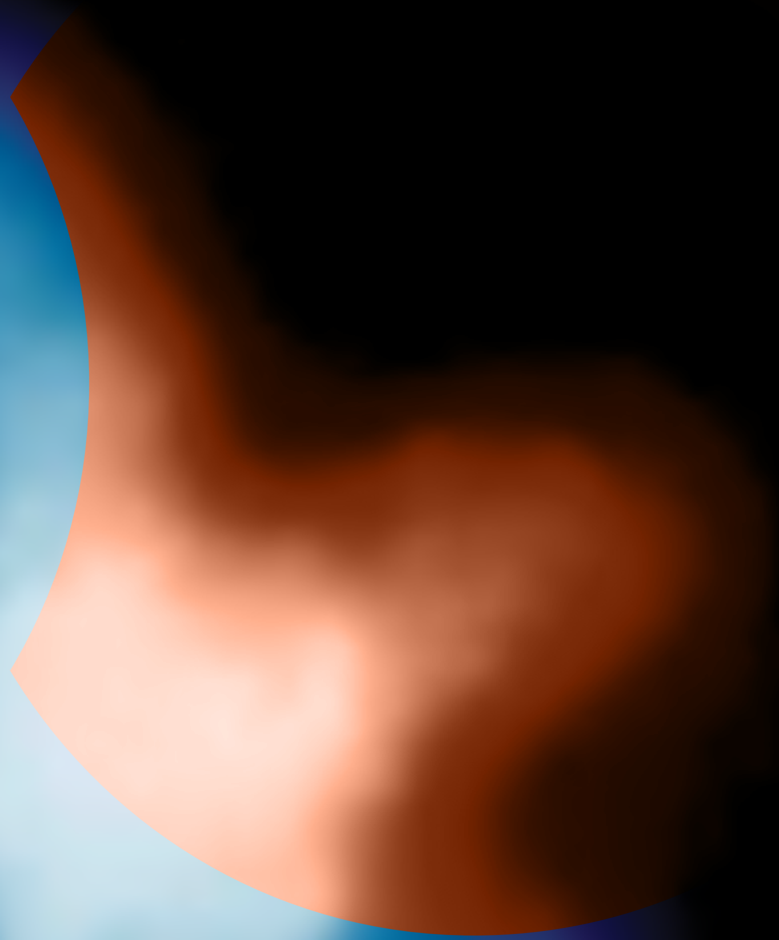
Milestones Achieved:

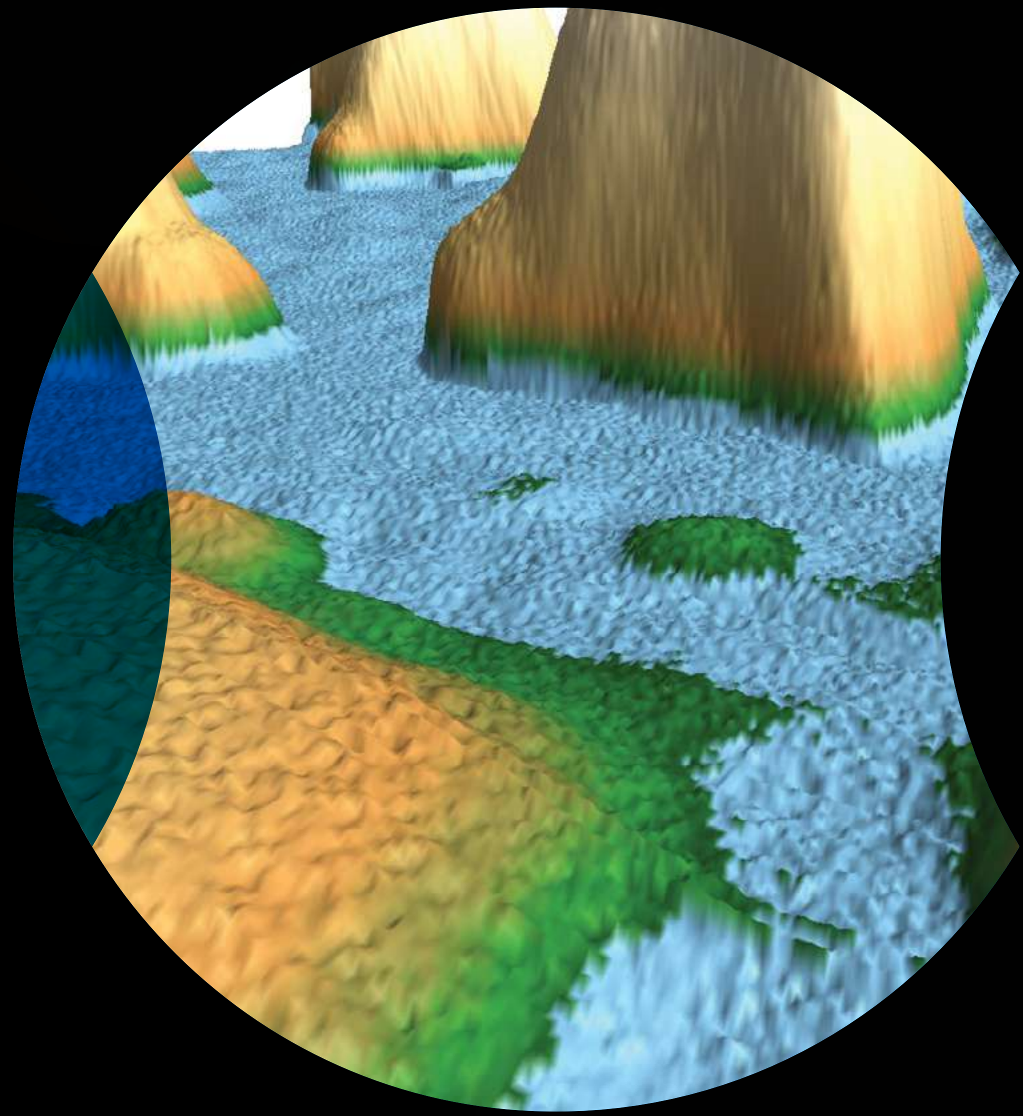
The identification of epitope candidates was achieved. This provides the means for raising captured monoclonal antibodies. The synthesis of synthetic peptides will commence shortly.

Project Potential:

The development of a saliva-based point-of-care (POC) immunoassay for COVID-19 detection (with longer-term potential for exploiting the testing data for the purpose of producing a synthetic vaccine).

Recruitment Of World-Class Researchers





Research Profile & **Summary for New Scientific Investigators**

Dr. *Yuval Boneh*

The Dept. of Earth and Environmental Sciences

Ben-Gurion University of the Negev

Background:

Dr. Yuval Boneh began his academic career at the Hebrew University of Jerusalem, where he studied Geology and Philosophy in a dual track program. He then received a master's degree in Geology from the Univ. of Oklahoma. He remained in the U.S. for his doctoral studies, receiving his Ph.D. in Geophysics from Washington University in St. Louis. Dr. Boneh was then accepted to a postdoctoral research position at Brown University in Providence, Rhode Island. While studying for advanced degrees in the U.S., Dr. Boneh focused on topics such as the mechanics of rock faults, Earthquakes and seismic observations, flow in the Earth's deep mantle layer and deformation mechanisms of minerals and rocks that can flow viscously or fracture in a brittle fashion.

Research Approach:

Dr. Boneh's research encompasses the mechanical and dynamic features of rocks, the constitutive of planet Earth and other terrestrial planets. Earth is a dynamic body that includes slow movement of rigid plates, accompanied by events of high stress release through Earthquakes, and material flow beneath the plates.

His interests lie in the overall dynamics of the Earth, from the shallow crust to the deep mantle. He uses experimental methods and microstructural analysis of natural samples to explore the underlying physics of deformation in geomaterials as revealed in the micro and nano scales of the crystal structure. His micro-level work has important implications for the macroscale study of the Earth's dynamics at depths of hundreds of kms.

As an illustrative example, his work elucidates observations connected to plate tectonics such as the way rocks flow beneath the plates (e.g., continents) and the conditions under which stress is released in the form of an Earthquake.

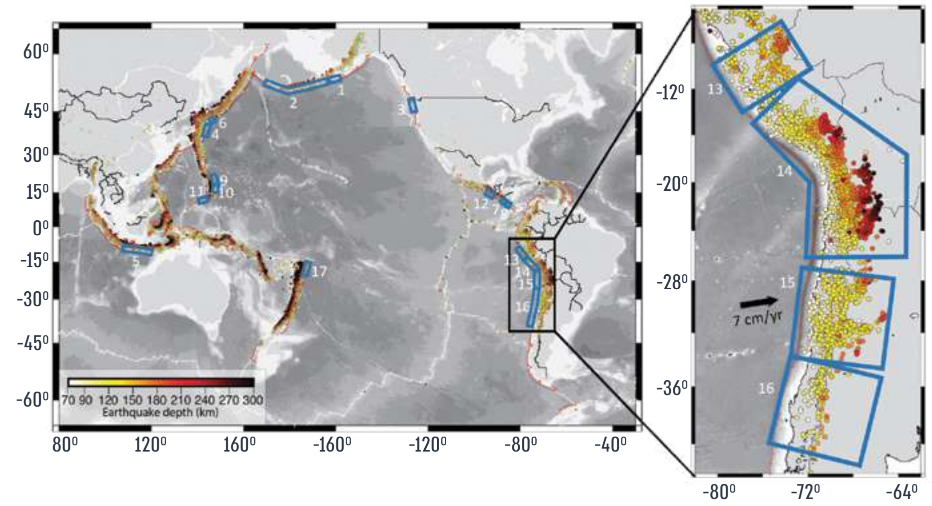
Dr. Boneh makes use of the Electron Back-Scatter Diffraction (EBSD) sensor installed in the scanning electron microscopy (SEM) unit in the IKI. The EBSD is a powerful tool in the study of the agents of deformation at the micrometer scale inside grains in order to relate them to processes at the 1000s km scale of tectonic plates.

Geophysical Research Letters

Vol. 46, Issue 7 / 16 April 2019 Pages: 3571 – 4065

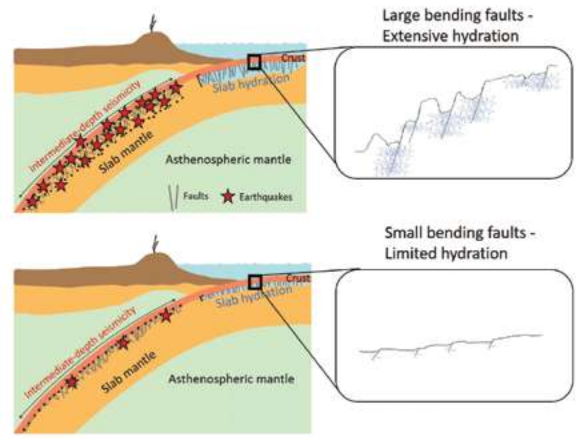
Corresponding Author: Yuval Boneh

https://doi.org/10.1029/2018GL081585



Title:

Intermediate-Depth Earthquakes Controlled by Incoming Plate Hydration Along Bending-Related Faults



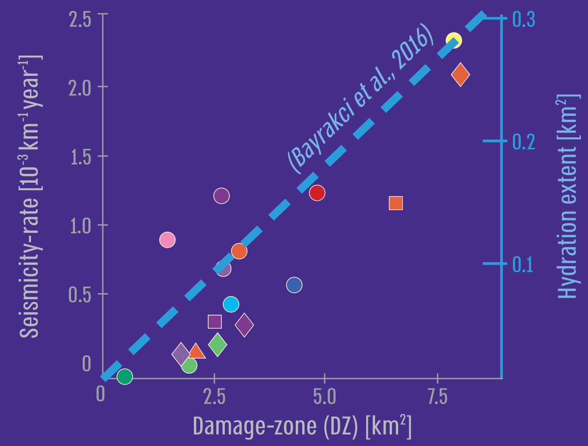
Abstract:

Intermediate-depth earthquakes (focal depths 70–300 km) are enigmatic with respect to their nucleation and rupture mechanism and the properties controlling their spatial distribution.

Several recent studies have shown a link between intermediate-depth earthquakes and the thermal-petrological path of subducting slabs in relation to the stability field of hydrous minerals.

Here we investigate whether the structural characteristics of incoming plates can be correlated with the intermediate-depth seismicity rate. We quantify the structural characteristics of 17 incoming plates by estimating the maximum fault throw of bending-related faults. Maximum fault throw exhibits a statistically significant correlation with the seismicity rate.

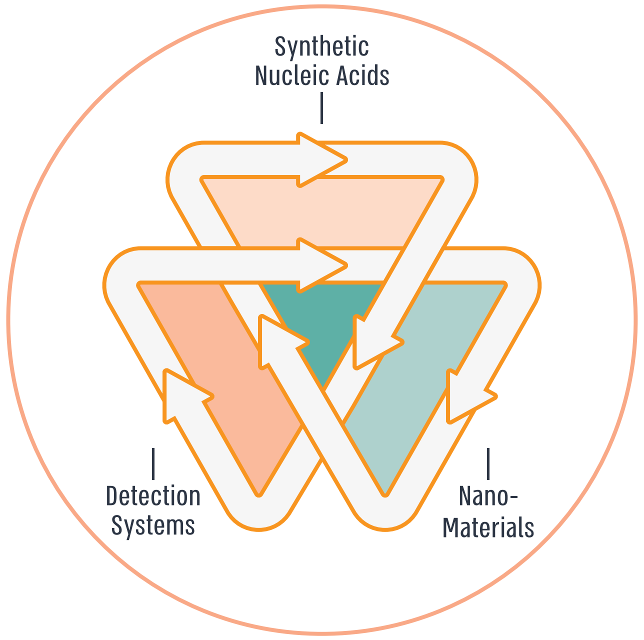
We suggest that the correlation between fault throw and intermediate-depth seismicity rate indicates the role of hydration of the incoming plate, with larger faults reflecting increased damage, greater fluid circulation, and thus more extensive slab hydration.



Prof.
Yossi Weizmann

The Chemistry Dept.

Ben-Gurion University of the Negev



Background:

Prof. Yossi Weizmann began his academic career at the ORT Braude Academic College of Engineering in Carmiel, where he received his bachelor's degree Cum Laude in Biotechnology Engineering. He then received a master's degree in Biotechnology from The Hebrew University of Jerusalem. His doctoral degree in Chemistry was awarded from The Hebrew University of Jerusalem based on his theses "Biosensors and Future Nanoscale Devices from Biomolecular Recognition Interactions."

Prof. Weizmann was then accepted to a postdoctoral research position at the Massachusetts Institute of Technology (MIT) in the U.S.

Before joining the faculty at BGU, he was employed as an Assistant Professor of Chemistry at the Univ. of Chicago. One of his specialty areas was the use of coatings on nanoparticles expanding the capabilities of the nanoparticles as "building blocks."

Research Approach:

Research in the Weizmann Lab is based on a multidisciplinary approach, interfacing biology, chemistry, nanotechnology, and materials science. This exciting frontier offers unparalleled opportunities for groundbreaking advances in the design of medical diagnostics and research platforms.

More specifically, Prof. Weizmann's research is concerned with the application of nanoparticles and nucleic acids, aimed at exploring and exploiting nanoscale advantages in the world of material chemistry, to address significant chemical, biochemical, and technological problems.

Prof. Weizmann's main research objectives are the development of novel strategies and approaches, providing versatile tools to form composite, nano-scaled, precisely-controlled structures and ultra-sensitive DNA machineries.

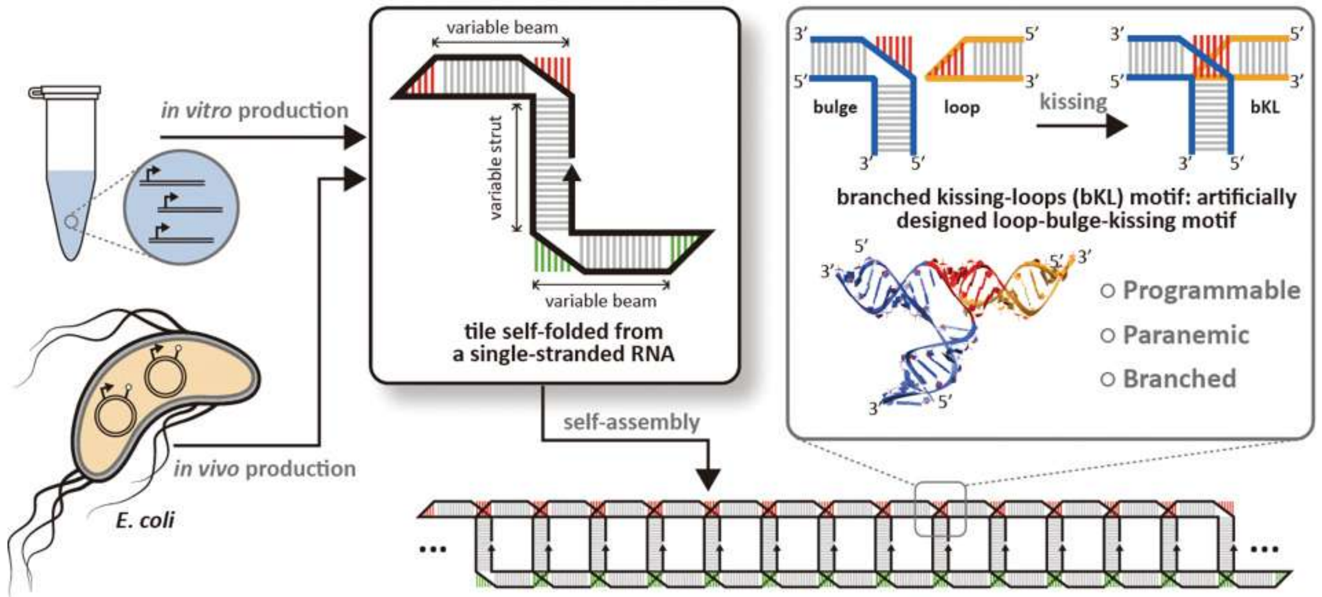
Title:

"Branched kissing loops for the construction of diverse RNA homooligomeric nanostructures"

Di Liu, Cody W. Geary, Gang Chen, Yaming Shao, Mo Li, Chengde Mao, Ebbe S. Andersen, Joseph A. Piccirilli, Paul W. K. Rothemund and Yossi Weizmann, Nature Chemistry, Vol 12, March 2020, 249–259

Abstract:

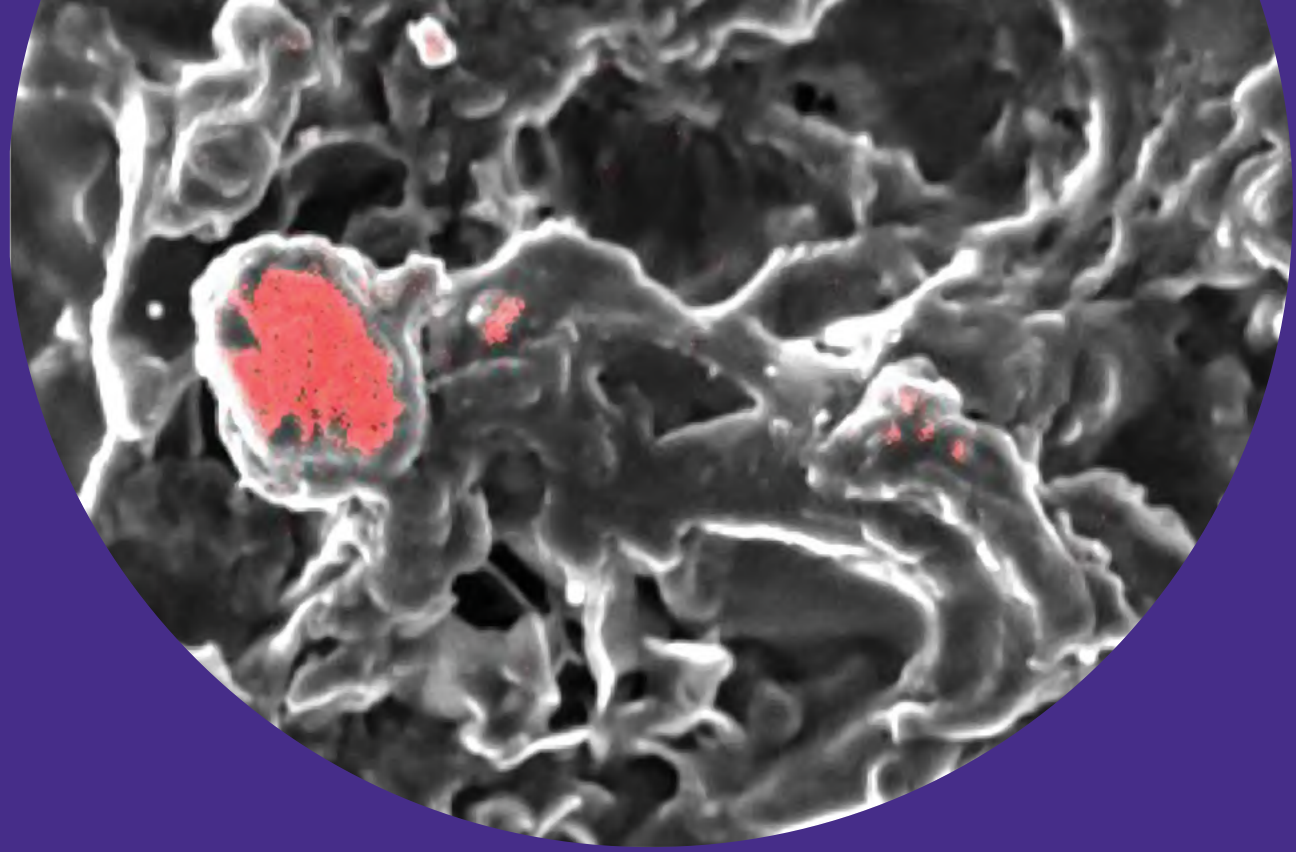
In biological systems, large and complex structures are often assembled from multiple simpler identical subunits. This strategy—homooligomerization—allows efficient genetic encoding of structures and avoids the need to control the stoichiometry of multiple distinct units. It also allows the minimal number of distinct subunits when designing artificial nucleic acid structures. Here, we present a robust self-assembly system in which homooligomerizable tiles are formed from intramolecularly folded RNA single strands. Tiles are linked through an artificially designed branched kissing-loop motif, involving Watson–Crick base pairing between the single-stranded regions of a bulged helix and a hairpin loop. By adjusting the tile geometry to gain control over the curvature, torsion and the number of helices, we have constructed 16 different linear and circular structures, including a finite-sized three-dimensional cage. We further demonstrate cotranscriptional self-assembly of tiles based on branched kissing loops, and show that tiles inserted into a transfer RNA scaffold can be overexpressed in bacterial cells.



Dr. **Netta Vidavsky**

The Dept. of Chemical Engineering

Ben-Gurion University of the Negev



Background:

Dr. Vidavsky studied chemical engineering and chemistry at Ben-Gurion University of the Negev (B.Sc.) and the Hebrew University of Jerusalem (M.Sc. with Prof. Shlomo Magdassi). She received a Ph.D. in structural biology from the Weizmann Institute of Science (with Profs. Lia Addadi and Steve Weiner). She then spent three years as a postdoctoral researcher in the lab of Prof. Lara Estroff at the Department of Materials Science and Engineering, Cornell University. In 2019, she joined the Department of Chemical Engineering at Ben-Gurion University as a Senior Lecturer. Her research interests include biomineralization, pathological calcification, and biomaterials.

Research Approach:

Dr. Vidavsky's research focuses on biominerals and their interactions with the surrounding tissue in disease by applying materials science and engineering strategies, such as biomaterials and advanced microscopy and spectroscopy. She actively contributes to advancing communication between the fields of engineering and medicine through collaborations with medical doctors in the areas of pathology, cancer, orthopedics, dentistry, and skeletal disease.

The Vidavsky lab characterizes the chemistry and structure of the cellular microenvironments in tissues as closely as possible to their native state – hydrated and with minimal processing – for a physiologically-relevant representation of the tissue structure, properties, and function. The tissues studied are both clinical samples and tissues engineered in the Vidavsky lab using 3D cell culture methodology.

The IKI is ideally equipped for many of the experimental approaches used by the Vidavsky lab. The relevant instruments of the institute include a new cryo facility with a high-resolution SEM equipped with cryo-EDS and high-pressure freezing and freeze-fracture devices, a confocal scanning laser microscope, and Raman and FTIR microscopes.

Title:

Multiple Pathways for Pathological Calcification in the Human Body. Advanced Healthcare Materials (2020): 2001271. Vidavsky Netta, Jennie AMR Kunitake and Lara A. Estroff.

Abstract:

Biomineralization of skeletal components (e.g., bone and teeth) is generally accepted to occur under strict cellular regulation, leading to mineral–organic composites with hierarchical structures and properties optimized for their designated function. Such cellular regulation includes promoting mineralization at desired sites as well as inhibiting mineralization in soft tissues and other undesirable locations. In contrast, pathological mineralization, with potentially harmful health effects, can occur as a result of tissue or metabolic abnormalities, disease, or implantation of certain biomaterials. This progress report defines mineralization pathway components and identifies the commonalities (and differences) between physiological (e.g., bone remodeling) and pathological calcification formation pathways, based, in part, upon the extent of cellular control within the system. These concepts are discussed in representative examples of calcium phosphate-based pathological mineralization in cancer (breast, thyroid, ovarian, and meningioma) and in cardiovascular disease. In-depth mechanistic understanding of pathological mineralization requires utilizing state-of-the-art materials science imaging and characterization techniques, focusing not only on the final deposits, but also on the earlier stages of crystal nucleation, growth, and aggregation. Such mechanistic understanding will further enable the use of pathological calcifications in diagnosis and prognosis, as well as possibly provide insights into preventative treatments for detrimental mineralization in disease.

High Impact Publications Authored by IKI Members

List of Publications with Impact Factor 10 and above

Luong DX., Yang KC., Yoon J., Singh SP., Wang T., **Arnusch CJ.**, Tour JM., *"Laser-Induced Graphene Composites as Multifunctional Surfaces"* **ACS NANO** 2019; Vol. 13, Issue 2, Pgs. 2579-2586. DOI:10.1021/acsnano.8b09626. [impact factor: 13.903]

Thamaraiselvan C., Wang J., James DK., Narkhede P., Singh SP., Jassby D., Tour JM., **Arnusch CJ.**, *"Laser-Induced Graphene and Carbon Nanotubes as Conductive Carbon-Based Materials in Environmental Technology"* **MATERIALS TODAY** 2020; Vol. 34, Pgs. 115-131, Review 7/293; Q1. [impact factor: 24.372]

Maity I.,Dev D.,Basu K., Wagner N., **Ashkenasy, G.**, *"Signaling in Systems Chemistry: Programing Gold Nanoparticles Formation and Assembly Using a Dynamic Bistable Network"* **ANGEWANDTE CHEMIE-INTERNATIONAL EDITION** 2020; Vol. 59, Pgs. 1-7. DOI:10.1002/anie.202012837. [impact factor: 12.959]

Frenkel-Pinter M., Samanta M., **Ashkenasy G.**, Leman, LJ., *"Prebiotic Peptides: Molecular Hubs in the Origin of Life"* **CHEMICAL REVIEWS** 2020; Vol. 120, Issue 11 Pages: 4707-4765. DOI:10.1021/acs.chemrev.9b00664. [impact factor: 52.76]

Maity I., Wagner N., Mukherjee R., Dev D., Peacock-Lopez E., Cohen-Luria R., **Ashkenasy, G.**, *"A chemically fueled non-enzymatic bistable network"* NATURE COMMUNICATIONS 2019; Vol. 10 Article Num 4636. DOI:10.1038/s41467-019-12645-0. [impact factor: 12.121]

Kroiss D., **Ashkenasy G.**, Braunschweig AB., Tuttle T., Ulijn RV., *"Catalyst: Can Systems Chemistry Unravel the Mysteries of the Chemical Origins of Life?"* **CHEM** 2019; Vol. 5, Issue 8, Pgs. 1917-1920. DOI:10.1016/j.chempr.2019.05.003. [impact factor: 18.205]

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Reddy SMM., Rasslenberg E., Sloan-Dennison S., Hesketh T., Silberbush O., Tuttle T., Smith E., Graham D., Faulds K., Ulijn RV., **Ashkenasy N.**, Lampel A., *"Proton-Conductive Melanin-Like Fibers through Enzymatic Oxidation of a Self-Assembling Peptide"*, **ADVANCED MATERIALS** 2020, Vol. 32, Article Num. 2003511 DOI:10.1002/adma.202003511. [impact factor: 27.398]

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Kadam SR., Enyashin AN., Houben L., **Bar-Ziv R.**, **Bar-Sadan M.**, *"Ni-WSe2 nanostructures as efficient catalysts for electrochemical hydrogen evolution reaction (HER) in acidic and alkaline media"* **JOURNAL OF MATERIALS CHEMISTRY A** 2020; Vol. 8, Issue: 3, Pgs. 1403-1416 DOI:10.1039/c9ta10990k. [impact factor: 11.301]

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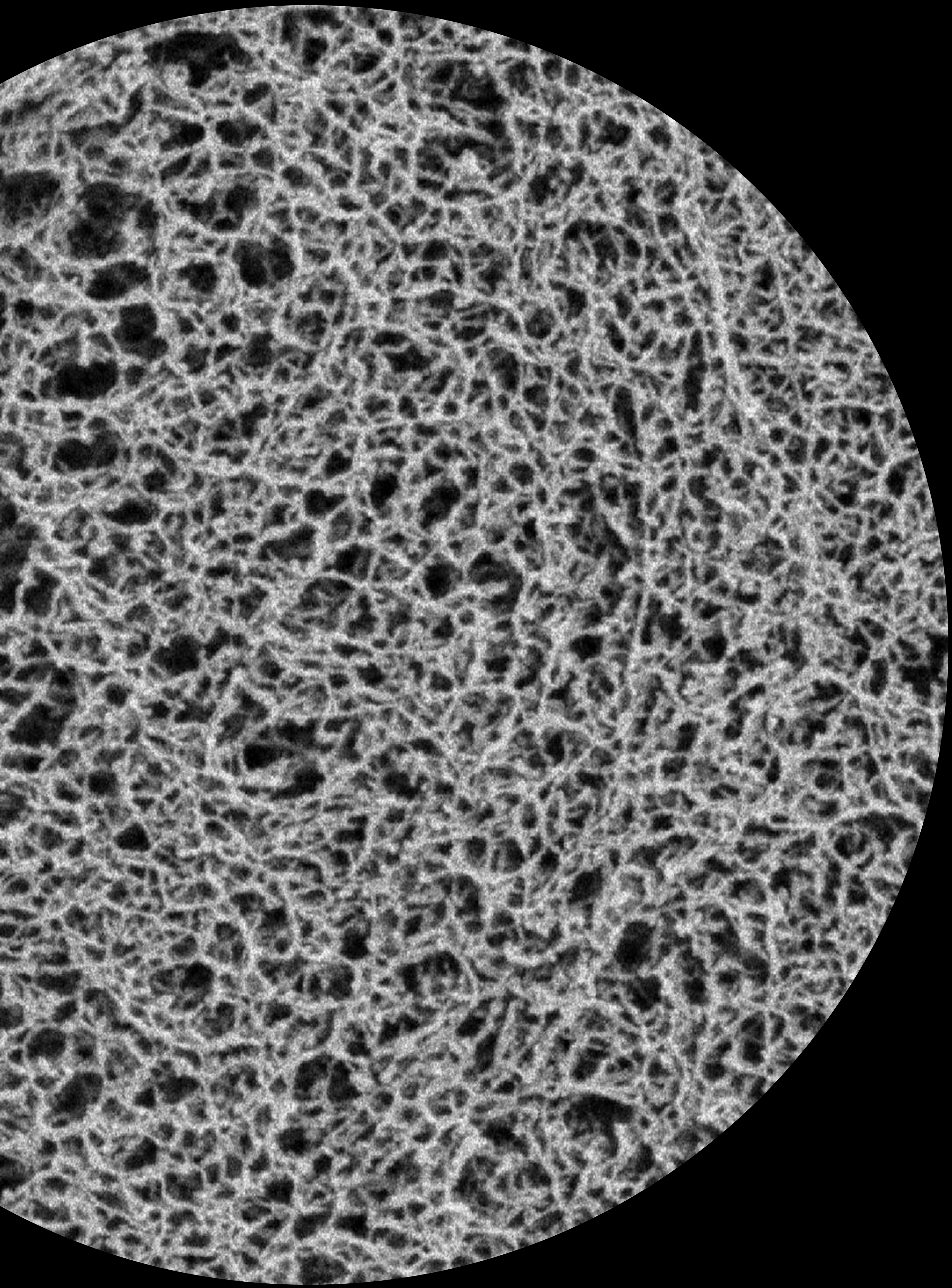

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