

2022/2023

Annual Review and Activity report

Y. Golan, Institute Director

**March 2024**

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Acknowledgments

The impressive progress of the IKI was only possible

due to the generous support of our donors:

* **Ruth Flinkman-Marandy**
* **Henry Weiss Family**
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* **Marty and Carol Weinberg**
* **Max and Rachel Javit**
* **Andrew and JJ Pheiffer**
* **להוסיף את גוזיק??**

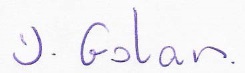
Dear Friends and Supporters of the Ilse Katz Institute for Nanoscale Science and Technology (IKI),

These times are particularly hard for us. With its main campus location in Beer-Sheva, Ben-Gurion University of the Negev (BGU) is the closest major university to the Gaza border. A staggering number of BGU community members have been impacted by Hamas' terrorist attack, including those who were killed, those who were injured, and those who lost their homes and were left devoid of their most basic personal belongings. *The critical role of BGU in rebuilding and supporting the Negev, and the community in the south of Israel has become more timely than ever before.*

While writing this letter, BGU student Noa Argamani is still held hostage by the Hamas terrorists in Gaza. Many of our students are still serving on the front lines, fighting Hamas and defending our borders from our enemies. Dozens of BGU employees and students are still evacuated from their homes, struggling to maintain a normal life. Large numbers of members of the BGU community, including staff, students, and faculty, are volunteering in multiple, diverse civil organizations to provide aid to both the battlefront as well as the home front. Despite the highly challenging situation, we are all working hard to promote the IKI, BGU, and the Negev Region in all of the University's undertakings including science, research, education, outreach, and technology transfer.

We are reaching out to you, our friends and fellow scientists, seeking your support in advocating in your community for the immediate release of all remaining hostages, and in donating to the funds established at BGU for supporting our activities. Your involvement would mean a lot to us.

Sincerely yours,



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, and 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 Ilse Katz Institute (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 greater sub-nanometer resolution) for the IKI. Listed below are several representative examples of equipment acquisitions in 2022-2023.

**Large Equipment** - The Planning and Budgeting Committee (PBC), a sub-committee of the Israeli Council for Higher Education, has established a competitive program for institutional scientific equipment. Its purpose is to fund large instrument items, which serve the needs of a wide range of research areas and researchers. This program is based on a minimum of 25% matching by the university, illustrating the need and importance of our donor base.

Over the past two years, the IKI sponsored three winning proposals, demonstrating the strength of our research program as viewed through the eyes of the scientific committee of the PBC.

**State-of-the-Art X-Ray Photoelectron Spectroscopy System**

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.

**The XPS system (Escalab Xi) was installed at the IKI in March of 2022.**

**State-of-the-Art Cryogenic Transmission Electron Microscope**

In recent years high-resolution cryogenic electron microscopy has been a game changer in biological research, and recent advancements in this state-of-the-art imaging technique have revolutionized the field of structural biology and become a vital tool in that area, as well as in cellular biology, biochemistry, pharmacology, and virology. The cryo-TEM has the outstanding ability to visualize atoms of soft materials (i.e., biological samples, including proteins). This equipment illuminates the sample with a "wide," planar electron beam and generates images by "sensing" the aberrations to the planar beam induced by the charges of the sample’s atoms.

The information provided by cryo-TEM is crucial for a variety of research applications such that the cryo-TEM has made a substantial contribution to the thrust of research at BGU across several disciplines. Examples include the study of the 3D structure of proteins, nucleic acids, and protein-nucleic acid complexes (life sciences), the determination of the 3D structural organization of large organelles, viruses, and whole cells, and 3D structure-based drug design (pharmaceutical industry).

*BGU has clearly become a leading center for cryo-EM in Israel, combining state-of-the-art equipment with cutting-edge know-how and expertise. As a result, a considerable number of research groups from other Israeli Universities choose to carry out their cryo-EM research at the IKI/BGU.*

**A Cryo-TEM (Glacios, Thermo-Fisher) equipped with the state-of-the-art direct electron detector, Falcon 4 coupled to Selectris X energy filter was installed at the IKI in September 2022.**

**Spectra 200 Scanning Transmission Electron Microscope for materials Research**

Transmission electron microscope (TEM) imaging is one of the most powerful characterization tools available, providing invaluable information regarding the behavior and properties of materials. While improved resolution is a key advantage of TEM imaging, its dominance in materials characterization stems from its ability to (1) combine high-resolution imaging with electron diffraction from small areas in the specimen, (2) enable chemical analysis at the atomic level, including tomography capabilities which allow for the reconstruction of 3D structures, and (3) generate dark field images from well-defined diffracted beams. The **Thermo-Fisher Spectra 200** represents a cutting-edge reinforcement to our research arsenal, offering enhanced imaging resolution, and advanced analytical capabilities. A multitude of nanoscale imaging modes are possible with the new instrument, including scanning TEM (STEM) and energy dispersive spectroscopy (EDS) carried out with 4 detectors simultaneously, allowing for quantitative monitoring of changes in the elemental composition of the sample with improved detection limits.

The advanced capabilities of the TEM allow IKI scientists to reveal the structure, morphology, and composition of samples, yielding quantitative insight into fundamental processes in solid-state physics and chemistry and providing invaluable information regarding the behavior and properties of materials. The TEM enables our researchers to perform cutting-edge research and is vital to their ability to remain at the forefront of materials science.

**The TEM (SPECTRA 200, Thermo-Fisher) was installed at the IKI in December 2022.**

**High-energy X-RAY DIFFRACTION (XRD) system**

The new XRD system constitutes a significant upgrade to existing systems by affording the ability to interpret structures at a much higher structural resolution than is possible with current diffractometers. In contrast to most diffraction devices that use a low-energy copper (Cu) source, the new XRD system utilizes a silver (Ag) source, generating X-rays with three times greater energy. When researching disorder in materials and studying materials with small structural changes beyond what can be resolved using a Cu source, having a high-energy X-ray source is essential. The system allows for the characterization of a wide range of samples including powders, thin films, crystalline materials, nano-crystalline materials, and glasses in reflectance and transmission geometries. These capabilities enable a diverse array of advanced structural characterizations that are not achievable with current devices, serving a variety of research needs at the university. Importantly, the Ag source provides resolution similar to that often achieved in synchrotron-based dedicated light sources (with longer acquisition times), providing an avenue to perform synchrotron-level experiments in-house.

The new system can also perform temperature-dependent measurements enhancing the *in-situ* capabilities of the XRD system through the heating and cooling of the sample stage for measurements in different atmospheric environments.

**The high-energy XRD system (Malvern Panalytical) was installed at the IKI (building 51) in September 2023.**

**Automated Microscope for Live Cell Imaging**

As part of expanding capabilities at the IKI in the field of bio-imaging, the decision has been made to acquire a high-throughput imaging system. This microscope performs automated imaging on a large number of samples, particularly for live cell imaging.

**The Celldiscoverer 7 (CD7) Automated Microscope for Live Cell Imaging** enables the study of biological processes in real time, providing a better understanding of the dynamic nature of living cells, thereby contributing to advancements in cell biology and related fields.

**This system was installed in December 2022 in the Bioimaging Unit (building 51) of the IKI.**

**Plasma-Enhanced Chemical Vapor Deposition (ICP-CVD) System**

ICP-CVD is used to deposit highly uniform thin films (up to a few microns) over large areas at a relatively low temperature (less than 350°C) with a high deposition rate. High-quality optical materials, such as Si3N4 waveguides, can be deposited by ICP-CVD. Other materials typically deposited using this system include SiO2, SiON, Si, Diamond-like carbon, and SiC, which can be deposited at temperatures between 100ºC and 400ºC. The low-temperature deposition facilitates control over parameters such as refractive index, hardness, stress, electrical properties, and others. Due to the excellent quality of materials obtainable through this approach, ICP-CVD can lessen residual stress in the resultant films while improving the deposition of films up to a few microns thick. The ICP-CVD at BGU is unique in its ability to deposit stress-free high-quality and high-purity optical materials, particularly materials used in making waveguides for quantum communication.

**An Oxford Plasma-Enhanced Chemical Vapor Deposition system was installed in the nano-FAB in May 2022.**

**Orion 8 UHV Sputtering System**

Sputtering is a precise thin film deposition technology. It offers excellent control over thickness and uniformity, making it ideal for optics, electronics, and surface applications. The system's compatibility with pressure-controlled reactive gases (Nitrogen and Oxygen) allows for compound film formation, while its scalability supports large-area substrate coating. The system offers a wide range of operation modes, including DC (up to 700 W), pulse DC (up to 2 kW), RF (up to 300 W), and RF bias (up to 50 W), allowing for the deposition of layers with precise ferromagnetic properties.

**An Aja Orion 8 UHV Sputtering System was installed in the nano-FAB in May 2022.**

**E–Beam and thermal Evaporation System**

The combination of an electron gun with an integrated thermal deposition system offers a powerful solution for precise thin film deposition. The e-gun generates a high-energy electron beam that can heat and evaporate target materials, enabling controlled vaporization. The system also enhances control over film thickness, composition, and uniformity. This setup is suitable for semiconductor manufacturing, optics, and thin film applications, where high-quality coatings with specific material properties are required.

**An AJA e-gun and thermal system was installed in the nano-FAB in May 2022.**

**Thermal table-top Atomic Layer Deposition**

Atomic Layer Deposition (ALD) is an advanced thin film deposition technique characterized by its precision and control at the atomic level. In an ALD system, thin films are deposited layer by layer through self-limiting chemical reactions. This process allows for highly conformal and uniform coatings on complex three-dimensional surfaces with precise thickness control.

**The GEMStar XT Thermal table-top ALD was installed in the nano-FAB in January 2022.**

**Stylus Profiling System**

The Dektak XT Profilometer is an advanced metrology tool designed for precise and non-destructive surface topography measurements. The system utilizes stylus profiling technology, where a sharp stylus is mechanically scanned across the sample surface. The stylus measures surface features with high accuracy, providing detailed information about roughness, step heights, and other topographical characteristics. With sub-nanometer resolution capabilities, the Dektak XT is capable of capturing even the finest details of surface morphology. This profilometer is widely used in research and development applications.

**The Bruker Dektak XT Profilometer was purchased in July 2023 and was installed in February 2024.**

**MLA 150 Advanced Maskless Aligner system**

The Heidelberg MLA150 is a state-of-the-art maskless lithography system for direct wafer writing. It can expose the patterns directly without prior fabrication of a mask. The maskless approach leads to a significantly shorter, more flexible, and cost-effective fabrication process with high resolution. The system can produce structures down to 1 μm and can expose very thick photoresists (~100 µm) while maintaining a vertical feature sidewall, which is very important in various applications and cannot be achieved using a traditional Mask Aligner system. In addition, the instrument contains features such as topside and backside alignment mechanisms with alignment accuracy better than 500 nm, grayscale exposure mode, and lithography on non-planar or curved substrates, covering a wide range of applications. Moreover, The MLA 150 has a unique exposure technique that utilizes a Spatial Light Modulator as a programmable photomask. In this method, the design layout is converted into a pixel image, that is exposed by projecting each pixel onto the photoresist through the optical system. The areas of application include MEMS, micro-optics, sensors, diffractive optical elements, electronic components, and many more.

**The Heidelberg MLA150 Maskless Aligner system was purchased in March 2022 and planned to be installed in May 2024**

**JA Woollam RC2 Spectroscopic Ellipsometer System**

The JA Woollam RC2 Spectroscopic Ellipsometer is a cutting-edge instrument designed for comprehensive thin film characterization. With a wide spectral range, it covers the UV to NIR wavelengths (250 nm to 1700 nm), enabling detailed analyses of material properties. The system's capability to measure spectra at multiple incidence angles facilitates the analysis of complex multilayer thin films. Automated mapping capabilities contribute to enhanced efficiency, while the ability to measure anisotropic materials broadens its applicability. For versatility, the RC2 ellipsometer incorporates a temperature-dependent stage, accommodating studies involving temperature variations. The system offers spatial resolution below 10 microns, providing detailed insights into surface features. The JA Woollam RC2 Spectroscopic Ellipsometer stands out as a powerful tool for precise and reliable thin film analysis.

**The JA Woollam RC2 Spectroscopic Ellipsometer was purchased in August 2023 and is planned to be installed in May 2024.**

**Super Inkjet Printer**

Super Inkjet technology is an advanced inkjet microdeposition technology. It allows for ultra-precision printing down to the submicrometer scale by producing ultra-microscopic droplets much smaller than the droplets ejected by a conventional inkjet printer (1/10 smaller in size and 1/1000 smaller in volume). The printer enables single-micron scale patterns (comparable to the photolithographic methods) to be drawn directly under normal temperature and normal atmospheric pressure. The Super Inkjet Printer employs a range of materials, including metal inks (conductive inks), insulating inks, resists, solvents, protein materials, and more. These materials can be seamlessly applied to various substrates including silicone, polyimide, and PET.

**The Super Inkjet printer (SIJ-S050) was purchased in December 2023.**

**Meeting the needs of IKI researchers in 2024-2025: plans for acquisition**

**State-of-the-Art Integrated Lattice-SIM2 SMLM Microscope (3.6 M ILS secured from VATAT out of 5.1 M ILS required)**

**Primary Researchers and Intended Use:**

**Prof. Natalie Elia** – Resolving mammalian ESCRT complex structural remodeling during cytokinesis

**Prof. Daniel Gitler** – Assessing the effect of alpha-synuclein variants on presynaptic structure and function

**Prof. Mark Schvartzman** – Revealing the spatial mechanism of receptor signaling in cytotoxic lymphocytes

Super-resolution microscopy techniques revolutionized the field of cellular imaging by enabling, for the first time, the visualization of proteins and organelles within cells at single-molecule resolution. Among these super-resolution techniques are structured illumination microscopy (SIM), which provides a twofold increase in resolution (~120 nm) over other conventional techniques, and single-molecule localization microscopy (SMLM; e.g., STORM/ stochastic optical reconstruction microscopy), which provides a tenfold increase in resolution (20–30 nm(.

This system offers vast new imaging possibilities for the developmental biology, neurobiology, chemistry, cellular biology, and materials engineering communities at BGU.

**A Laboratory for *In-Situ* Transmission Electron Microscopy (TEM) (4.5 M ILS requested from VATAT out of 7.5 M ILS required)**

**Primary Researchers and Intended Use:**

**Prof. Yuval Golan** - Chemical epitaxy of semiconductor thin films; surfactant-assisted nanocrystal synthesis

**Prof. Maya Bar-Sadan** - Nanocrystals growth, catalytic properties of nanostructures, photothermal properties of nanostructures

**Dr. Yevgeny Rakita** - Nano-scale structural and chemical evolution in functional glasses; evolution of phase-change-materials

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 it is a major tool for understanding the structure, morphology, and chemical composition of materials. The requested microscope is designed for the fast, precise, and quantitative characterization of materials.

It will be equipped with the following features:

• High-resolution imaging in scanning and transmission modes

• High-angle annular dark-field imaging (HAADF)

• Energy Dispersive X-ray Spectroscopy (EDS)

• Holders for ***in-situ* TEM** (liquid cell holder, including potentiostatic control, gas phase holder, sample temperature control, etc.)

This configuration is optimal for (i) elucidating the atomic/molecular structure of materials; (ii) imaging with ultrahigh resolution for the identification of microstructures and defect structures; (iii) compositional characterization using EDS at a sub-nanometric spatial resolution; and (iv) *in-situ* TEM to study the behavior of materials under different environments.

*In-situ* TEM has become an essential tool in materials science, nanotechnology, chemistry, and biology, providing a dynamic and detailed view of nanoscale phenomena under a variety of conditions.

**Cryogenic Focused Ion Beam Scanning Electron Microscope (Cryo-FIB-SEM) (4.5 M ILS requested from VATAT out of 10.6 M ILS required)**

**Primary Researchers and Intended Use:**

**Prof. Itzik Mizrahi** - Microbiology and microecology

**Dr. Daniel Gitler** - Synaptic transmission

**Dr. Netta Vidavsky** - Biomineralization

**Dr. Benjamin Palmer** - Bio-inspired materials, bio-photonics and bio-crystallization

In recent years, high-resolution cryogenic electron microscopy has been a game changer in biological research, and recent advances in this state-of-the-art imaging technique have revolutionized the field of structural biology such that it has become a vital tool in that area, as well as in cellular biology, biochemistry, pharmacology, and virology.

Obtaining high-resolution insight into the living cell requires cryo-FIB-SEM, which overcomes sample thickness limitations. Cryo-FIB-SEM allows for the precise milling of snap-frozen biological samples with nanometric accuracy. By combining cryogenic sample preparation with focused ion beam milling and scanning electron microscopy, this approach has become the state-of-the-art method for high-resolution imaging of *in-situ* large and complex biological samples. The controlled thinning of the samples, with high 3D localization precision, facilitates the determination of high-resolution structures of biological targets inside cells.

Cryo-FIB-SEM will be used to advance our understanding of materials and biological systems at sub-nanometric resolutions. The combination of the advantages of cryogenic sample preservation and high-resolution imaging will offer unprecedented insights into the structural and compositional details of diverse, mostly biological, specimens.

**High-End 300 kV Cryogenic Transmission Electron Microscopy (cryo-TEM) Laboratory at BGU (18 M ILS requested from VATAT out of 34 M ILS required)**

**Primary Researchers and Intended Use:**

**Dr. Liron David, Dr. Gabriel Frank, Dr. Iris Grossman-Haham, Prof. Raz Zarivach** - Structural biology

**Prof. Leah Gheber -** Mitotic dynamics

**Prof. Nurit Ashkenasy -** Bio-inspired materials

**Prof. Niv Papo** - Protein design

The development of direct electron detectors and the advances in computational tools have positioned cryo-EM as the leading technique for high-resolution macromolecular structure determination.

Importantly, cryo-EM is a highly versatile structure-determination technique, enabling diverse use cases such as the analysis of targets in their cellular or organelle context and of complexes with conformational variability, varied stoichiometries, and small-molecule additives.

This current evolution of the cryo-EM methodology allows scientists all over the world to tackle biological research questions that were inaccessible until recently.

Establishing a high-end cryo-EM laboratory at BGU will allow all Israeli researchers to leverage the numerous advantages of this technology, moving from the analysis of isolated, rigid macromolecular complexes to a wider and more comprehensive context of cellular biology, soft matter, and pharmacology.

**Femtosecond Laser Micromachining System (700 KEuro required)**

The Femtosecond laser (FSL) micromachining system is a powerful tool for direct (maskless) patterning with high resolution and a high aspect ratio. This technique exhibits excellent capabilities in performing the 2D+ and 3D processing of a variety of materials such as silicone, glass, sapphire, and metals, among others. These materials are routinely used in nanofabrication facilities for various research activities. Many important applications require access to an FSL laser system. These include high-quality quantum-integrated photonic components, surface micro- and nano-structuring, refractive index modification inside bulk materials, selective layer removal, and cutting brittle materials. These applications are relevant in a wide range of fields, such as micro-optics, nano-photonics, and quantum optics. The FSL system is an important tool for the fabrication of complex structures that require the removal of material. In addition, this system enables the fabrication of complex shaped waveguides by changing the local reflecting index inside the bulk material.

**High-Resolution 3D Printer (700 KEuro required)**

High-resolution 3D printers enable the fabrication of nano and microstructures in various optical devices, with feature sizes starting from about 100 nanometers, and heights of up to several millimeters. The 3D microprint process can directly fabricate on already existing devices including functional micro-optical components from polymers or metals, depending on the particular system type. The 3D printer is based on the two-photon polymerization of photosensitive polymers by high-powered ultrashort laser pulses. By focusing the laser beam into the transparent photoresist, the material polymerizes exclusively within the highest-intensity region of the focal volume (and not along its beam path). The 3D printer is required to fabricate nano and micro-structures such as MEMS, 3D-printed low-loss fiber-to-chip couplers, chip-to-fiber connectors, lenses, and many other free-form structures.

**Chemical Mechanical Planarization (CMP) System (400 K$ required)**

Chemical Mechanical Planarization is a process that combines mechanical polishing and chemical etching that can remove topography from wafer surfaces. It is a crucial process in manufacturing for achieving flat and smooth surfaces on various materials. The CMP system is required for multilayer fabrication with surface planarization.

**Bioprinter (250 KEuro required)**

A bioprinter is an advanced and innovative technology designed for the precise deposition of biological materials, including living cells, to create three-dimensional structures resembling living tissues. This cutting-edge device plays a pivotal role in the field of biotechnology and biomedical engineering, offering numerous applications in regenerative medicine, drug discovery, and tissue engineering.

**High-resolution electron microscope (SEM ) for the cleanroom (350 KEuro required)**

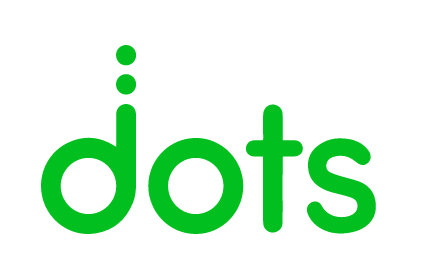
A High-Resolution Scanning Electron Microscope (SEM) is an advanced imaging instrument that utilizes electrons instead of light to achieve remarkable levels of magnification and resolution in the nanoscale range. SEMs offer exceptionally high magnification capabilities, enabling the visualization of structures at the nanoscale. The resolution can reach sub-nanometer levels, providing detailed insights into the surface morphology of specimens. The SEM system plays a crucial role in our nanofabrication center, serving as our primary means of overseeing and controlling the ongoing processes within the facility.

**The equipment will be operating in designated laboratories at the IKI, and administered by the IKI management to the benefit of the entire research community in BGU, as well as research groups from other Universities and from Industry.**

**Special achievements, Commercialization, and Patents**

**Prof. Shlomi Arnon**

# Optical probe for the *in situ* measurement of nitrate in soil

A pioneering company, DOTS, has developed a groundbreaking system for measuring soil levels of nitrate — an essential nutrient for plant growth. Spearheaded by the expertise of Dr. Elad Yeshno, Professor Ofer Dahan, and Professor Shlomi Arnon from BGU, this technology employs a sophisticated sensor to collect and analyze soil water, delivering real-time insights into nitrate levels. By providing farmers with actionable data, this system enables informed decisions on fertilizer application, effectively preventing overfertilization. The repercussions of excessive fertilization, including financial waste, resource depletion, and environmental pollution, are mitigated through DOTS' innovative approach, ultimately conserving valuable resources and safeguarding the environment.

In the realm of agriculture, a persistent challenge revolves around using fertilizers efficiently and responsibly without compromising environmental or human health. DOTS, a revolutionary electro-optical sensor and information system, addresses this challenge head-on. This technology provides real-time data on soil nitrate levels, empowering farmers to tailor fertilizer applications to the precise needs of their crops. The result is a reduction in overfertilization and underfertilization, mitigating environmental impacts such as groundwater contamination, air pollution, and greenhouse gas emissions associated with excess nitrate leaching or runoff. Additionally, the DOTS technology could enhance crop productivity and quality by optimizing nutrient availability and balance. With its simple and effective solution for fertilizer management, DOTS' technology stands poised to significantly impact global agriculture, sustainability, and the health of the global population.

This innovative solution's core is a state-of-the-art system that employs an array of light sources and sensors complemented by cutting-edge hardware and advanced algorithms. This system features a suction mechanism that emulates plant roots, securely extracting water samples for analysis. Its dual functionality is evident in one set of light sources and detectors measuring light absorption at specific wavelengths, reflecting nitrate and DOC levels, and another set gauging light emission at a different wavelength, indicating DOC concentration. Including an analysis unit employing a unique signal processing algorithm and advanced machine learning algorithm ensures precise calculations of nitrate and DOC concentrations.

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**Prof Gil Shalev**

# A New Method Towards Biosensing with Biological Transistors for Homecare and POC Medical Diagnostics

A crucial demand in healthcare is for diagnostic platforms that enable point-of-care testing. On-site testing at family clinical practitioners, care facilities, or bedside in hospitals can support early diagnosis and clinical decision-making, both of which directly translate into saving lives and improving patients’ quality of life. However, the transition of healthcare services into point-of-care testing is greatly hindered by the lack of enabling technologies combining miniaturization with accuracy, ease of operation, multiplexing, and low costs needed for feasible mass production.

Transistor-based biosensing is the ‘holy grail’ of diagnostics. The convergence of the diagnostics industry with the existing advanced microelectronics chip industry ensures the utilization of the most advanced high-volume production technology available today for biomedical applications, enabling stability, robustness, low noise levels, and signal amplification. This directly translates into quantitative diagnostics with a high degree of sensitivity, limit-of-detection, and dynamic range. Crucially, the extreme miniaturization of transistor-based biosensing supports multiplexed sensing from ultra-small samples which cannot be realized using any other extant technology. **Despite this, after 40 years of research, there is no transistor-based specific and label-free sensing platform commercially available for medical diagnostics.**

Recently, the BGU team developed and reported a new type of biological transistor that overcomes known hurdles associated with the realization of transistor-based diagnostics. The invention demonstrated high-quality sensing of analytes including PSA, AFP, ferritin, and estriol in diluted serum. It was also demonstrated to be suitable for the sensing of Botulinum toxin activity, organophosphate binding in neutral solutions, and DNA-enzyme interactions in neutral solutions for drug development applications, while also enabling the sensing of infection-related biomarkers in undiluted, unfiltered milk. **The invention is protected by eight patent applications.**

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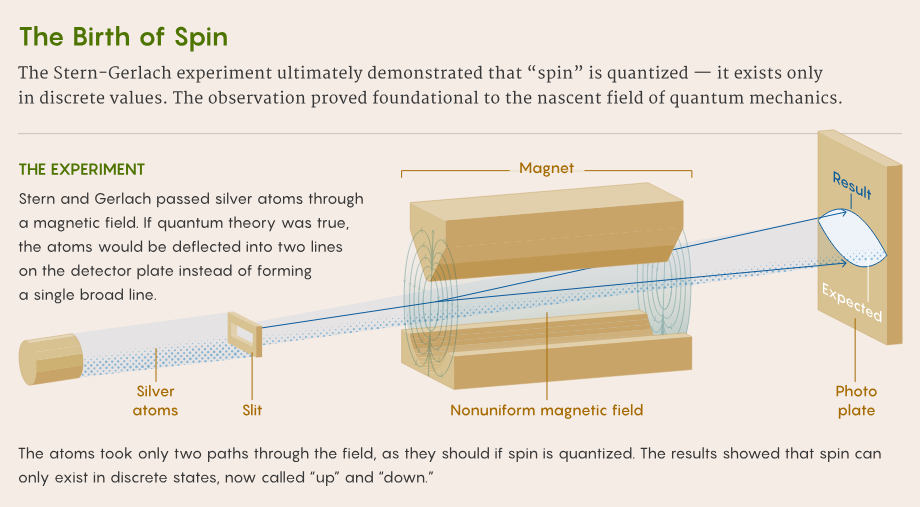
This BioFET technology’s innovative design offers a novel, label-free method for the precise sensing of ferritin and other biomolecules in minuscule sample sizes. By expertly managing the complexities of the solid-biological interface, this unique BioFET system ensures unparalleled accuracy and reliability in detecting crucial health markers. Ideal for medical diagnostics, clinical research, and pharmaceutical testing, this technology heralds a new era in healthcare, offering sensitive, consistent, and specific biomarker detection, embracing an advancement in biosensing that promises to revolutionize medical diagnostics and personal health monitoring.

**Prof Ron Folman**

From Quanta Magazine

# The (Often) Overlooked Experiment That Revealed the Quantum World

*A century ago, the Stern-Gerlach experiment established the truth of quantum mechanics. Now it’s being used to probe the clash of quantum theory and gravity.*



The article explains that to verify the “quantumness” of Stern and Gerlach’s experiment, one has to recombine the two beams appearing in the figure and to search for what is called an interference pattern. The article describes the difficulty in achieving this recombination and provides the analog that it is as difficult as putting together broken eggshells (or in reference to the children's rhyme, putting Humpty Dumpty back together again). The article then states: In 2019, however, a team of physicists led by [Ron Folman](https://cris.bgu.ac.il/en/persons/ron-folman" \t "_blank) at Ben-Gurion University of the Negev [glued those eggshells](https://iopscience.iop.org/article/10.1088/1367-2630/ab2fdc" \t "_blank) back together. “They were able to put Humpty Dumpty back together again,” Friedrich said. “It’s beautiful science, and it’s been a huge challenge, but they’ve been able to meet it.”

Aside from helping to verify the “quantumness” of Stern and Gerlach’s experiment, Folman’s work offers a new way to probe the limits of the quantum regime. Today, scientists still aren’t sure just [how big objects can be](https://www.quantamagazine.org/how-big-can-the-quantum-world-be-physicists-probe-the-limits-20210818/) while still adhering to quantum commandments, especially when they’re large enough for gravity to intervene. In the 1960s, physicists [suggested](https://pubs.aip.org/aapt/ajp/article-abstract/31/1/6/1037984/The-Problem-of-Measurement?redirectedFrom=fulltext" \t "_blank) that a full-loop Stern-Gerlach experiment would create a super-sensitive interferometer that could help test that quantum-classical boundary. In 2017, physicists expanded that idea and suggested shooting tiny diamonds through two neighboring Stern-Gerlach devices to see if they gravitationally interacted.

Folman’s group is now working toward that challenge. In 2021, they [outlined](https://www.science.org/doi/10.1126/sciadv.abg2879" \t "_blank) a way to beef up their single atom-chip interferometer for use with macroscopic objects, such as diamonds comprising a few million atoms. Since then, they’ve shown in a [series](https://journals.aps.org/prresearch/abstract/10.1103/PhysRevResearch.4.023087" \t "_blank) [of](https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.130.113602" \t "_blank) [papers](https://arxiv.org/abs/2305.15230" \t "_blank) how splitting larger and larger masses will again be Sisyphean, but not impossible, and could help solve a slew of quantum gravity mysteries.

“The Stern-Gerlach experiment is very far from completing its historical role,” Folman said. “There’s still much that it’s going to give us.”

"Together, Math and Science Foundations Fund 'Tabletop' Physics That Could Transform Our Understanding of the Universe"

Physics breakthroughs don’t always require city-sized particle colliders or giant radio telescope arrays. The Gordon and Betty Moore Foundation, the [Simons Foundation](https://www.simonsfoundation.org/" \t "_blank" \o "Simons Foundation), the [Alfred P. Sloan Foundation](https://sloan.org/" \t "_blank" \o "Alfred P. Sloan Foundation), and the [John Templeton Foundation](https://www.templeton.org/" \t "_blank" \o "John Templeton Foundation) have partnered to fund 11 innovative “tabletop” experiments, many of which will explore realms of physics typically probed by large-scale facilities.

The newly funded projects, selected from hundreds of proposals, include hunting for dark matter, building ultra-precise atomic clocks, and examining the intersection of general relativity and quantum mechanics. These ambitious experiments all aim at expanding the frontiers of fundamental physics while still fitting into a typical room-sized university physics research lab.

By pooling their resources and expertise, the foundations have magnified the impact of their grantmaking and are able to collectively fund more projects. Each of the projects will receive funding for up to five years, with the four foundations together pledging $30 million for all the undertakings.

**Ron Folman of Ben-Gurion University of the Negev in Israel** won one of these grants and he will lead the development of a nanodiamond spatial interferometer to help resolve the disconnect between quantum physics and general relativity by performing spin-based interferometry measurements.

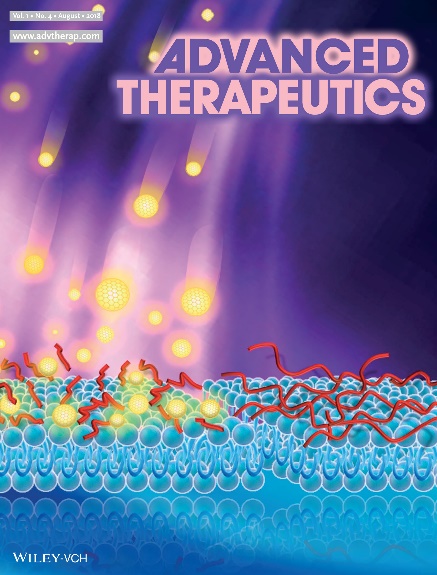
**Education:**

***Educational activities of the IKI continued as appropriate in 2022-2023, based on well-established precedent.*** This included nano workshops and seminars, undergraduate and graduate academic programs in nanoscience/nanotechnology (NS/NT), and the active participation of the IKI in the incorporation of nanoscience modules in the curriculum of relevant departments on campus.

In addition to these endeavors, IKI staff members conducted a series of specialized academic courses tailored to meet evolving educational demands. Among these offerings were "Metabolomics for Biomedical Studies," "Introduction to Basic Spectroscopic Techniques," and "Membrane Proteins: Structure and Function." These courses represent cutting-edge domains, empowering students to deepen their understanding and proficiency in utilizing advanced instrumentation and techniques available at IKI. Through such educational avenues, the IKI continues to foster a dynamic learning environment, equipping students with the expertise necessary for their research.

Undergraduates

In total, 13 (6 in 2022 and 7 in 2023) outstanding students graduated from the IKI’s specialized undergraduate nanotechnology program, based on a “double major” program of study, culminating in two distinct B.Sc. degrees: one in Chemistry and one in Chemical Engineering. Separately, 11 (6 in 2022 and 5 in 2023) students began their undergraduate studies – all with the highest credentials.

Doctoral Students

In 2010 the IKI decided to adapt to the highly interdisciplinary nature of nanoscience, initiating a unique, interdisciplinary Ph.D. program encouraging student mobility across traditional dividing lines.

In 2023, two students graduated from this program:

**Dr. Elad Arad** – Dr. Arad completed all of his degrees at BGU. In his undergraduate studies, he studied both Chemistry (major) and Philosophy (minor). He studied for his Master’s in the Department of Chemistry, supervised by Prof. Raz Jelinek and Prof. Hanna Rapaport from the Department of Biotechnology Engineering. From his Master’s to his Ph.D., he focused on “soft matter’ nanoscience in the area of peptide assemblies and specifically the surface phenomena of b-sheet-forming peptides, developing nanoparticles to modulate the folding of peptides and studying their properties in relation to amyloidogenic diseases while linking them to catalytic processes. During his Ph.D. at the IKI, Elad’s research achievements were recognized through several prizes such as the Zvi Shariv Prize for excellent Chemistry student (Given by ADAMA LTD, 2018), the Dean of Natural Sciences excellence award (BGU, 2018 and 2019), the Dean’s list of Kreitman School of Advanced Studies (BGU, 2022), the Leviner travel scholarship (BGU, 2019 and 2023), the Lindau meeting with Nobel laureates scholarship (Lindau Foundation, 2022), and the Japanese Society for the Promotion of Science (JSPS) HOPE fellowship (HOPE 14 meeting, Japan 2023). His work at IKI resulted in the publishing of 16 papers, including 8 on which he is the first author. Since April 2023, Elad is a Rothschild postdoctoral fellow in the group of Prof. Oleg Gang, Department of Chemical Engineering at Columbia University in New York City. His current work is focused on the development of editing tools for DNA nanotechnology.

**Dr. Aabha Bajaj** - Dr. Bajajwas an international student at IKI for her Ph.D. studies under Prof. Ibrahim Abdulhalim. Her thesis was focused on the bio-functionalization of plasmonic substrates for sensitive and specific biosensing applications like the detection of fungi DNA, viruses, small contaminants, and bacteria, as well as real-time monitoring biofilms. She advanced several applications for novel plasmonic concepts and miniaturized devices that were being developed in the Nanophotonics lab of her supervisor such as high penetration depth plasmonic substrate, phaseshift SPR, and portable SPR systems (PhotonicSys, PlasmetriX). She concluded her Ph.D. with 3 first-author papers in sensor-based journals and 3 co-authored research articles. She also contributed to one book chapter on Molecularly imprinted polymer-based sensors. She was selected to participate in ERASMUS+ exchange program and received a scholarship to conduct a part of her thesis at TU Berlin. She presented two of her works at an international conference on Biosensing technologies in Barcelona in 2022. After completing her Ph.D., she continued her work with Prof. Ibrahim developing biosensing assays for foodborne pathogens using a miniaturized SPR device. During her studies, Dr. Bajaj took part in 6 publications, 3 of them as first author. Currently, she is actively looking for post-doctoral positions in the field of biosensors and bioanalytics.

The two graduate students contributed to 3 High Impact Factor publications as first authors as detailed in the High Impact Publications section of this report.

Specialized Training and Customized Exposure for Students in Selected Areas

* The 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
* Chemical vapor deposition (CVD) laboratory course for materials engineering students
* Hands-on introduction to cleanroom processes for electrical engineering and biotechnology engineering students.
* 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.

**RECRUITMENT OF WORLD-CLASS RESEARCHERS**

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

**Dr. Iris Grossman-Haham**

**The Dept. of Life Sciences**

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**Background:**

Dr. Grossman-Haham studied biology and chemistry at The Hebrew University of Jerusalem (B.Sc.). She received a Ph.D. in structural biology from the Weizmann Institute of Science under the mentorship of Prof. Deborah Fass. She then spent 4.5 years as a postdoctoral researcher in the lab of Prof. Ron Vale at the University of California, San Francisco. In late 2021, she joined the Department of Life Sciences at Ben‐Gurion University as a Senior Lecturer. Her research focuses on understanding the mechanisms of flagellar beating using biochemistry, structural biology, and advanced cryo-electron microscopy.

**Research Approach:**

The research in Dr. Grossman-Haham's laboratory is multidisciplinary, combining genetics, mechanics, and chemistry. The group studies flagella, molecular machines that convert chemical energy to mechanical movement, thereby propelling cells and facilitating swimming. As in any machine, the architecture and composition of flagella dictate its function. Thus, Dr. Grossman-Haham's laboratory invests in dissecting the structure and molecular organization within flagella to unravel the mechanisms that underlie flagellar motility. As flagella comprise over 500 different proteins, the lab uses an integrative approach of determining the three-dimensional structures of individual components and visualizing the entire flagellum at high resolution using cryo-electron microscopy. These experiments are supported by IKI equipment, specifically, the cryo-TEM Talos F200C and the Thermo Fisher Scientific Glacios. The high-resolution structural information obtained is crucial for developing molecules that would improve or perturb flagella motility. For example, Dr. Grossman-Haham's laboratory studies the flagella of the parasite *Leishmania*, the cause of the severe, globally neglected disease leishmaniasis. Currently, there is no efficient treatment for leishmaniasis. Since the parasite depends on its flagellum for its survival, the flagellum serves as an attractive target for leishmaniasis treatment or prevention. At the same time, the flagellum—a swimming device designed by nature—could inspire the development of synthetic microswimmers for drug delivery, noninvasive imaging, and other applications. The research in Dr. Grossman-Haham's laboratory provides the groundwork for engineering such treatments and devices.

**Dr. Moshe Harats**

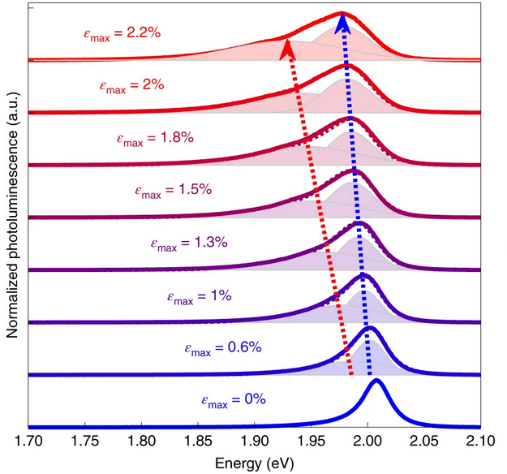
**The Department of Materials Engineering**

**Background:**

Dr. Harats studied physics and general history at the Hebrew University of Jerusalem (B.Sc.). He continued his M.Sc. and Ph.D. in physics under the supervision of Prof. Ronen Rapaport from the Racah Institute at the Hebrew University of Jerusalem. He then spent three years as a postdoctoral fellow at Freie University in Berlin, under the supervision of Prof. Kirill Bolotin. In 2021, Dr. Harats joined the Department of Materials Engineering at Ben Gurion University of the Negev. His research interests are the optical and mechanical properties of thin, 2-dimensional materials, including quantum phenomena.

**Research approach:**

Dr. Harats’ research focuses on 2D materials from the class of transition-metal dichalcogenides (TMDCs) that are widely researched around the world due to their unique electronic and optical properties. To name a few, TMDCs are semiconductors with a direct bandgap at the monolayer regime. In addition, they can sustain very large strains (>15%), making them appealing for flexible electronics. They can be used as quantum materials as well, as they host single photon emitters, a crucial ingredient for future quantum communication protocols, and excitons which are excited states that have a quantum mechanical nature.

The expertise of the lab is centered on the combination of the mechanical strain of TMDCs and optical investigations. We perform experiments at cryogenic temperatures, where these interesting phenomena persist, analyzing single photon emitters, quantum condensation, and transport of excitons. We are interested in the physics of TMDCs and in exploiting their flexibility. As an example, we can create a “funnel” to concentrate charge carriers in a small area to enhance the performance of photovoltaic cells by simply applying a well-defined elastic deformation to the TMDCs.

The IKI is ideally equipped with many instruments that are crucial for the research conducted by the Harats lab. The relevant instruments include Raman spectroscopy, a FIB, and FTIR microscopes.

**Title:** “[Dynamics and efficient conversion of excitons to trions in non-uniformly strained monolayer WS2](https://www.nature.com/articles/s41566-019-0581-5)”, M. G. Harats, J. N. Kirchhof, M. Qiao, K. Greben, and K. I. Bolotin, *Nature Photonics* **14**, (2020)

**Dr. Yevgeny Rakita**

**The Dept. of Materials Engineering**

**Background:**

Dr. Rakita completed his Ph.D. at the Weizmann Institute of Science studying the fundamentals of Halide Perovskite materials. He continued his postdoctorate training at the Data Science Institute of Columbia University in the group of Professor Simon Billinge. Studying Total Scattering and Pair-Distribution-Function analysis, he focused on Data-Driven material discovery, where in collaboration with Prof. Taheri's group he developed 'SNEM' - a new data-driven quantitative technique for studying disordered materials at high (nm) spatial resolution. In 2022 he joined the Materials Engineering Department at the Ben Gurion University of the Negev as an Assistant Professor. His research focuses on the fundamental understanding of stability and the evolution of meta-stable materials.

**Research Approach:**

In our lab, we target meta-stable materials that often include high degrees of disorder, such as glasses, high-entropy alloys, phase-change materials, and self-healing semiconductors. All these exotic systems exist within a transition, which in return provides a wide variety of potential new applications. They are targeted as materials for renewable energy (solar cells), thermal energy storage, key components for future computation (neuromorphic/ in-memory computation), and novel bio-compatible prostheses.

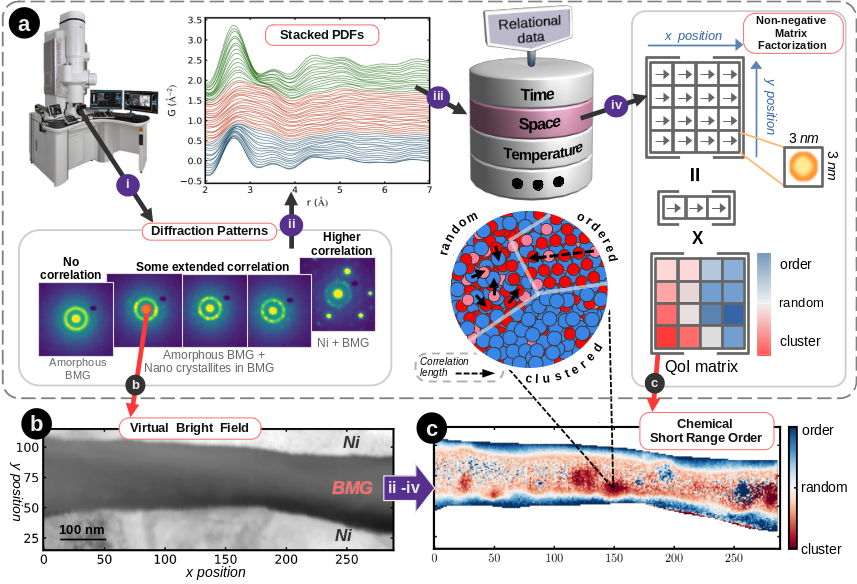
Materials that undergo transitions often tend to exist in states with a high degree of disorder, thus requiring non-traditional approaches to create links between their structure and functionality. Often, these systems are dynamically changing during their functionalization. Therefore, to understand them and rationally guide their development into future technologies one must follow and control their structural evolution. We develop experimental and analytical data-driven tools to learn about the structural evolution from the earliest stages of their ordering, try to understand what (de)stabilizes them, and how one can control their evolution.

**How do we do it?**

* We develop state-of-the-art high-resolution tools, which implement data-driven experimental approaches, for in-situ/operando structural evolution investigations.
* We develop and implement machine learning and image-processing algorithms for disentangling phase-complexity and targeting desired meta-stable phases.
* We develop active control approaches of functionalizing meta-stable and regenerative materials, meaning materials that undergo cyclic degradation/ self-healing processes.

The IKI nano center is a perfect setting for pushing our ideas to the edge, with its unique complement of leading experts who operate first-class equipment and the wide array of instruments that support our many research needs, providing a robust foundation for our work. Recently, the IKI center received a hard-radiation powder diffractometer. Ordered according to our specifications, this instrument can mimic the high structural resolution an experiment in a synchrotron can provide without leaving the institute. In addition, a unique scanning electron diffraction system was also recently obtained, providing mapping capability to better understand structural evolution in amorphous systems at the highest spatial resolutions.

One leading example in our group is a project focused on the machine learning (ML)-assisted evolution discovery of meta-stable structures. We developed nano-meter resolution ML-based analyses for disentangling structural order in meta-stable structures. Combining ML tools with relational diffraction data from scanning transmission electron microscopes (4D-STEM), we developed the Scanning Nano-Structure Electron Microscope (SNEM) technique. - a tool for mapping the local ordering distribution and its evolution at nano-scale resolution. The development of SNEM should provide insight into nano-meter-sized structural events in meta-stable systems, which were previously believed to be uniform due to a lack of probing resolution and efficient data analysis, which are now available.



**Figure from a recent publication showing the ability to provide unique local structural information from amorphous materials, which uses machine learning and can lead to novel breakthroughs in understanding how materials evolve from their very first steps.**  (see: *Mapping structural heterogeneity at the nanoscale with scanning nano-structure electron microscopy (SNEM)*. Rakita et at., Acta Materialia, 242, 118426 (2023) )

**Dr. Galit Katarivas Levy**

**The Dept. of Biomedical Engineering**

A person smiling at the camera

Description automatically generated**Background:**

Dr. Galit Katarivas Levy is a researcher in the field of biomaterials and 3D printing, with a unique and strong background in materials science and engineering, biomechanics, and tissue engineering. She received her B.Sc., M.Sc. (magma cum laude), and Ph.D. from the Department of Material Engineering, Ben-Gurion University of the Negev, Israel, in 2008, 2010, and 2016, respectively. She completed postdoctoral fellowships at the University of Cambridge, UK, in the Department of Engineering, Division C - Materials Engineering & Material-Tissue Interactions. In 2020, she joined the Department of Biomedical Engineering at Ben‐Gurion University as a Senior Lecturer, where she is the head of the Biomaterials & 3D-printing Laboratory (GKLab).

**Research Approach:**

Dr. Katarivas Levy's research focuses on developing advanced biomaterials and using additive manufacturing (AM) technologies for tissue engineering, regenerative medicine, and healthcare applications. She actively contributes to advancing communication between engineering and medicine through close collaborations with surgeons based at Soroka Medical Center from oral and maxillofacial surgery, orthopedics, and neurosurgery departments. The GKLab is focusing on using AM to create the next generation of patient-specific bone replacement implants based on high-performance polymers that can promote bone tissue regeneration and enhance integration with the host tissue. Furthermore, the lab is interested in developing hybrid composites using a two-step method combining AM technologies with conventional casting. Initially, a reinforced lattice structure is fabricated via AM. Then, the reinforced lattice is infiltrated by casting with a molten matrix and at a lower melting temperature, resulting in a bi-continuous interpenetrating phase composite structure.

The IKI is ideally equipped for many of the experimental approaches used by the GKLab. The relevant instruments of the institute include a Dual Beam focused ion beam scanning electron microscope (FIB-SEM) system, transmission electron microscopy (TEM), X-ray micro-computed tomography (X-μCT), and differential scanning calorimetry (DSC).

A diagram of different types of structures

Description automatically generated

**Title**: Effect of the lattice structure on the interface zone and the final properties of novel PrintCast Ti64-AlSi9Cu3 interpenetrating phase composites, Tulapn I, Snir Y, Halevi S, Emuna M, Bitton N, Meshi L, Katarivas Levy G. (2024) Additive manufacturing. 79, 103902.

**Dr. Muntaser Naamneh**

**The Physics Dept.**

**Background:**

Dr. Muntaser Naamneh began his academic career at the Technion-Israel Institute of Technology, where he received his bachelor's degree in *m*athematics and physics. He then continued his studies at the same institute and received master's and Ph.D. degrees based on his thesis, “ARPES measurements in the presence of electrical current in cuprates.” He then spent three years as a postdoctoral researcher at the synchrotron at the Paul Scherrer Institute in Switzerland. In 2019, he joined the Department of Physics at Ben Gurion University as a senior lecturer. His research interests include tailoring the properties of quantum materials to investigate novel phenomena and employing them for novel devices with new functionalities and technological applications.

**Research Approach:**

Dr. Naamneh 's research focuses on studying the microscopic electronic structure of quantum materials with the aim of discovering new phenomena in this class of materials. He is now interested in growing thin films atomic layer by layer from different materials and tailoring their properties to host new phases with unique properties such as high-temperature superconductivity (materials with zero resistance to electrical current), metal-insulator transition, and topological states. Advancing the knowledge on this topic paves the way for harnessing these properties for novel devices with new functionalities and technological applications.

The IKI is ideally equipped for many of the experimental approaches used by the Naamneh lab. The relevant instruments of the institute include X-ray diffractometers, high-resolution Scanning Electron Microscopy equipped with elemental analysis (EDS), and Fourier transform infrared spectrometers.

**Dr. Gabriel Frank**

**The Dept. of Life Science**

**Background:**

Dr. Gabriel Frank began his academic career at the Technion Israel Institute of Technology, studying Physics and Material Science. He then received a master's in Material Science and Engineering from Ben-Gurion University of the Negev (BGU). During his M.Sc. studies, Gabriel became interested in the complexity and intricacies of molecular structures produced by living organisms. Following his interest, Gabriel switched fields to Biophysics during his Ph.D. at the Weizman Institute of Science, where he studied the dynamics of molecular machines at a single molecule level.

Before being accepted to BGU, Dr. Frank took a postdoctoral research position at the National Institutes of Health in Bethesda, MD, USA, where he continued his research on molecular machines using Cryo-Electron Microscopy (Cryo-EM), a groundbreaking macromolecular imaging technique. In BGU, Gabriel spearheaded the adaptation of this technology, making BGU the national leader in this field.

**Research Approach:** The research in Gabriel’s lab combines functional and structural studies of proteins, aiming to understand the diversity of structural mechanisms enabling proteins to sense, integrate, and respond to cues from their environment. The research heavily depends on Cryo-Electron Microscopy and Cryo-Electron Tomography using our newly purchased Galcios Cryo-TEM.

To pursue these goals, Gabriel’s lab is working on three different prototypical model systems; all of them perform sophisticated tasks involving interactions and coordination with different factors. However, they are markedly different in their response mechanisms to the environment, as is evident from their diverse spectrum of structural dynamics. Mpa is on one extreme of this spectrum, a highly dynamic AAA+ proteasomal activator that translocates substrate proteins through its central pore, delivering them into the 20S proteasome for degradation. On the other extreme is ferritin (Ft), which has a very rigid structure and seems not to undergo conformational changes. Yet, it can change its mode of interaction with its diverse interacting partners in response to the level of iron stored in its internal cavity. Between these two opposing extremes lies the protective antigen (PA), the translocation machinery of the anthrax toxin. After assuming its membrane penetrating conformation, PA is almost static. Yet, it can harness pH differences as the driving force for protein translocation. Consequently, PA is a salient example system capable of integrating the different signals from the environment as a trigger for a major conformational change (the prepore to pore transition); and as a model system for protein translocation machinery, devoid of the conformational changes associated with most ATPases.

A structure of a molecule

Description automatically generated with medium confidenceThe Cryo-EM structure of the molecular interface between Ft and NCOA4 shows for the first time the structural basis for the intracellular regulation of ferritin degradation.

**Prof. Benjamin Palmer**

**Department of Chemistry**

**Background:**

Dr. Benjamin Palmer began his academic career at Cardiff University, where he received his master’s and Ph.D. degrees in the Chemistry Department based on his thesis, “Structural Properties, X-ray Birefringence and Crystal Growth of Solid Organic Inclusion Compounds”. He then took a postdoctoral research assistant position at the Centre for Nanohealth of Swansea University (Joint project between Swansea (Prof. Steve Wilks) and Texas A&M University (Prof. Kenith Meissner) and five years as a postdoctoral fellow and senior postdoctoral fellow at Weizmann Institute of Science. In 2019, he joined the Department of Chemistry at Ben Gurion University as an assistant Professor.

**Research Approach:** We are a multidisciplinary group sitting at the interface between materials chemistry, cell biology, and optics. We investigate how animals use highly reflective crystals to manipulate light to produce colors and in visual systems.

**Optically-Functional Organic Bio-Crystals**

Many optical phenomena in organisms are produced by the interaction of light with assemblies of highly reflective organic crystals. However, despite their widespread distribution in animals, little is known about the structure and properties of these materials. Now, the study of biologically formed organic crystalline materials (‘*Organic Biomineralization*’) is emerging as an exciting new discipline alongside the parent field of *Biomineralization*. It is well-established that high refractive index guanine crystals produce iridescent structural colors in animals such as fish, spiders, and crustaceans. Crystalline guanine is also utilized to construct mirrors in animal eyes used for image formation and enhancing photon capture. A common motif for guanine-based reflectors is that of multilayer stacks of plate-like crystals interspersed with cytoplasm in the form of a Bragg reflector. Reflectivity is produced by constructive interference of light reflected from the high/low refractive index interfaces.

**Theme 1: Biological Crystallization Mechanisms**

By controlling the structure, morphology, and organization of organic crystals, animals produce a raft of different optical 'devices'. A key question is: how do organisms exquisitely control the crystallization of the component organic molecules? We aim to unveil biology’s crystallization tricks which are far superior to state-of-the-art methods in solid state chemistry. To explore this question, we follow crystal formation processes in a range of model organisms undergoing development or regeneration. We study changes in crystal morphology and organization using cryogenic electron microscopy techniques, observing the biological tissues in their fully-hydrated, native state. *In situ* diffraction and spectroscopic tools are used to determine changes in the physical and chemical properties of the crystals during growth. Information from these approaches is then synthesized to gain insights into biological crystallization mechanisms. Our ultimate objective is to understand the underlying biological control behind these crystallization processes. Thus, we utilize genetic molecules to correlate gene expression with specific crystallization events during formation. We aim to reveal the key proteins and enzymes involved in initiating nucleation and directing crystal growth.

**Theme 2: New Biogenic Crystals with New Optical Functions**

To date, guanine crystals have been found in at least seven animal and plant phyla. However, aside from guanine, few other functional biogenic organic crystals have been reported, and those that have been reported are often poorly characterized. In recent years, two 'new' biogenic crystals, isoxanthopterin and 7,8-dihydroxanthopterin were reported in reflective structures in the eyes of shrimp and fish. These molecules belong to the pteridine family, which previously were thought to act exclusively as absorbing pigments in nature. These findings, together with other evidence in the literature, suggest that there are many more organic bio-crystals 'out there' to be discovered. This part of the group studies the materials chemistry of unexplored photonic structures in animals, where the identity and properties of the underlying optical materials are not known. We use *in situ* synchrotron X-ray diffraction, electron diffraction, and electron microscopy to characterize the structural and optical properties (e.g., crystal structure, crystal habit) of the component materials in these systems. By coupling this information with optical calculations and measurements (e.g., refractive index and reflectivity) carried out in collaboration with Prof. Dan Oron, Weizmann Institute of Science, we can rationalize the amazing optical properties of these biological photonic systems.

As well as being of fundamental interest, biogenic organic crystalline materials have the potential to inspire a new generation of bio-inspired and bio-friendly organic optical materials such as non-fading pigments, photonic paints, and digital display materials.

**High Impact Publications - List of Publications with Impact Factor 10 and above**

Shvalya, V.; Vasudevan, A.; Modic, M.; Abutoama, M.; Skubic, C.; Nadižar, N.; Zavašnik, J.; Vengust, D.; Zidanšek, A.; **Abdulhalim, I.**; Rozman, D.; Cvelbar, U. Bacterial DNA Recognition by SERS Active Plasma-Coupled Nanogold. *Nano Letters***2022***, 22*, 9757-9765 DOI:10.1021/acs.nanolett.2c02835. [IF 10.8]

**Bajaj, A.**; Abutoama, M.; Isaacs, S.; Abuleil, M. J.; Yaniv, K.; **Kushmaro, A.**; Modic, M.; Cvelbar, U.; **Abdulhalim, I.** Biofilm growth monitoring using guided wave ultralong-range Surface Plasmon Resonance: A proof of concept. *Biosensors and Bioelectronics***2023***, 228*, 115204 DOI:10.1016/j.bios.2023.115204. [IF 12.6]

Algov, I.; Feiertag, A.; **Shikler, R.; Alfonta, L**. Sensitive enzymatic determination of neurotransmitters in artificial sweat. *Biosensors and Bioelectronics***2022***, 210*, 114264 DOI:10.1016/j.bios.2022.114264. [IF 13.39]

Sharma, C. P.; **Arnusch, C. J.** Laser-induced graphene composite adhesive tape with electro-photo-thermal heating and antimicrobial capabilities. *Carbon***2022***, 196*, 102-109 DOI:10.1016/j.carbon.2022.04.041. [IF 11.307]

Dev, D.; Wagner, N.; Pramanik, B.; Sharma, B.; Maity, I.; Cohen-Luria, R.; Peacock-Lopez, E.; **Ashkenasy, G.** APeptide-Based Oscillator. *Journal of the American Chemical Society***2023***, 145*, 26279-26286 DOI:10.1021/jacs.3c09377. [IF 16.383]

Bar-Hen, A.; Hettler, S.; Ramasubramaniam, A.; Arenal, R.; Bar-Ziv, R.; **Bar Sadan, M.** Catalysts for the hydrogen evolution reaction in alkaline medium: Configuring a cooperative mechanism at the Ag-Ag2S-MoS2 interface. *Journal of Energy Chemistry***2022***, 74*, 481-488 DOI:10.1016/j.jechem.2022.07.020. [IF 13.4]

Ghosh, S.; Mondal, B.; Roy, S.; **Shalom, M.; Bar Sadan, M.** Alcohol oxidation with high efficiency and selectivity by nickel phosphide phases. *Journal of Materials Chemistry A***2022***, 10*, 8238-8244 DOI:10.1039/D2TA00863G. [IF 11.9]

Maurice, L.; **Bilenca, A.** Three-dimensional single particle tracking using 4pi self-interference of temporally phase-shifted fluorescence. *Light. Science & Applications***2023***, 12*, 58-7 DOI:10.1038/s41377-023-01085-7. [IF 20.257]

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