The Center for Nanoscience and Nanotechnology
Acknowledgements

All the activity and achievements described in this report would not have been possible without the support and help of numerous individuals and organizations. We are deeply grateful to them for their help and support.

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Starting from 2007 we participate in the Israel Nanotechnology National Initiative (INNI) program, founded by TELEM, with the total budget of 30M$ spread over the five academic years 2007-2011. The monitory resources are according to the triangle model in which the university, donors and the INNI initiative are contributing 10 M$ each.
Dear colleagues and friends,

I am delighted to present to you the Nano-center’s 2007-2008 annual scientific report. It highlights our scientific and organizational progress over the last academic year. Before diving into the wealth of material which follows, here is some brief information regarding our nano related activity.

Overall, last year, 158 nano-related papers, originating from 38 different research groups, have been published – many of them in highly ranked journals including Science, the Nature family, Physical Review Letters, PNAS, Nano Letters, JACS, Angewandte Chemie International Edition, etc. 67 of these articles are the result of cooperation with researchers from other universities.

We report on 61 various collaborative research projects nationally and internationally with other academic institutions as well as 11 research projects with industrial partners.

Tel Aviv University (TAU) researchers applied for 49 nano related patents - six of which have been approved during 2008. Four ties with industries have been signed – three of which are related to renewable energy. Several others are in the final stages of negotiations.

Continuing in our efforts to recruit new researchers, this year we have successfully recruited several outstanding investigators currently engaged in nano related research.

Dr. Dan Peer (Life Sciences) specializes in selective targeting and reprogramming of leukocytes using fully degradable nano-medications. Serving as a core member, Dan is assigned to help develop the nano-biology general research laboratory, which was established last year at the Nanocenter.

In addition, three new faculty members have joined the Nanocenter’s second circle:

Dr. Yael Roichman (Chemistry) specializes in Holographic tweezers and manipulation of nano-objects. While developing new methods in nano-manipulation, she will contribute to a large number of cooperative research projects in nanoscopy.

Dr. Oded Hod (Chemistry) specializes in computational methods for nano-objects, in particular carbon nanotubes and Graphene. He adds a strong theoretical perspective to the already existing experimental activity in these topics.

Dr. Ella Sklan (Medicine) specializes in understanding the life cycle of the Hepatitis C virus. Her work is aimed at developing new antiviral strategies. A major element of her research involves energy transfer using nanoparticles.

112 PhD and 108 MSc research students were involved in nano-research at TAU over the course of 2008. The MSc program in Materials and Nanotechnology has already passed all necessary internal (TAU) and external (Israeli Counsel of Higher Education) approvals. Budget has been allocated and the program is planned to begin in the following academic year. Our new weekly seminar program on materials and nanotechnology (23 seminars in 2008) achieved an attendance of ~50 MSc and PhD students, as well as many faculty members, each week. We have launched an exchange program of graduate students and senior scientists between Northwestern University and TAU. Five exchange scholarships have been granted.

“C” (TAU Micro and nano central characterization and fabrication facility) was inaugurated on October 2007. It now encompasses the majority of micro and nano fabrication as well as most of the characterization instrumentation on TAU’s campus. “C” is responsible for providing service, training and consultation to costumers as well as maintaining and upgrading its facilities. The facility serves 25 TAU research groups as well as 16 external academic and industrial users.
Major items that were purchased or installed in 2008 include:

**PPMS measurement station:** an important research tool for transport measurement in low temperatures and strong magnetic fields.

**Visualization and analytical characterization of biological nano system:** the system serves researchers from Biology and Medicine by helping them to visualize and analytically characterize tissues at a cellular resolution.

**NIL – Nano imprinting lithography system:** a tool for patterning nanostructures on hard and soft materials using stamps. TAU’s nano-imprinting system will be the first to be purchased and used in Israeli academia.

Next year we will continue in expanding the nano community, our resources and infrastructure. In the upcoming academic year we will continue our recruiting efforts and will focus on recruiting new core members in physics and medicine.

We will strengthen our fabrication capabilities by purchasing a focused ion beam lithography system. We are now in the final stages of the decision making and purchasing process. We will continue to develop the new laboratory dedicated to optical and electrical studies of neural networks. We consider this laboratory as the starting point for investigating the interface between biological and physical systems.

Looking forward to a productive new year.

Sincerely yours,

O. Cheshnovsky

Prof. Ori Cheshnovsky
Head of the Center for Nanoscience and Nanotechnology
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Cover picture in courtesy of: Dr. Shachar Richter and Ms. Netta Hendler.

Graphic Design: Michal Semo-Kovetz and Yael Kfir, TAU Graphic Design Studio
Tel Aviv University (TAU), recognizing the emerging needs and opportunities in the field of Nano Sciences and Nanotechnology (NST), established in 2000, the Center for Nanoscience and Nanotechnology (TAU Nanocenter). The center which encompasses activities across four faculties (Exact Sciences, Engineering, Life Sciences and Medicine), provides the intellectual framework for interdisciplinary research, and the technological infrastructure vital for nurturing leading-edge research in NST.

We believe that the mission of the Nanocenter can best be achieved by implementing and maintaining the following:

- Recruiting outstanding relevant researchers; developing and organizing needed infrastructure; developing focused research areas; Developing training and educational programs; establishing ties and services with academia and industry; generating IP with good prospects of commercialization; Promoting related academic activity and topical laboratories.

The TAU Nanocenter houses, within its approximately 1200 sq. meters, both public laboratories - operated and maintained by technical and administrative staff – as well as private research laboratories. These laboratories maintain state of the art equipment for construction, realization and general characterization of nano-structures.

As a means of catalyzing nano activity, the Nano center’s central premises host the laboratories of the core faculty members (so far, five were hired). These researchers represent the diverse expertise necessary for developing the new “nano-culture”. This core is extended and supported by additional “circle” of more than 50 research groups distributed in the four relevant faculties. Researchers in this “circle,” to various degrees, contribute to, and benefit from, the activities at the center.

The policy and development plans of the center are discussed and approved by a scientific committee which includes representatives from the four relevant faculties.

“C” (TAU Micro and nano central characterization and fabrication facility) was inaugurated in October 2007. The majority of the micro/nano fabrication and characterization instrumentation on the TAU campus is managed by “C”. “C” is in charge of providing service, training and consultation to costumers as well as maintaining and upgrading its facilities. The facility serves 25 TAU research groups, as well as 16 external academic and industrial users. The TAU nanocenter, relies in its operation, also upon the facilities of the Wolfson Materials Center (Auger spectroscopy, X-ray diffractometer, SIMS analysis, etc.).

More information on the TAU Nanocenter can be found in http://nano.tau.ac.il
Missions

- To provide Tel Aviv University users with access to state of the art micro and nano fabrication and characterization equipment.
- To train, consult and help users to operate the equipment and to develop suitable protocols.
- To provide services to external academic users as well as industrial users.

Equipment

- **Electron microscopes**
  - Environmental Scanning Electron Microscope (ESEM - FEI Quanta 200 FEG)
  - Field Emission High Resolution Scanning Electron Microscope (HRSEM - Jeol JSM-6700)

- **E-beam Lithography**
  - E-beam lithography (Raith 150)
  - SEM with e-beam writing attachment (Jeol 6400 + Elphy)

- **AFM/STM**
  - AFM (Molecular Imaging PicoSPM II)
  - AFM (Veeco NanoScope IV MultiMode)
  - Variable Temperature Ultra-High Vacuum STM/AFM System (Omicron)

- **AFM in a glove box** (NT-MDT SMENA-A)

- **Optical microscopy**
  - Metallurgical Confocal microscope (Olympus LEXT)
  - Measurement microscope (Hisomet II)

- **Photolithography**
  - Contact lithography (Suss MA6, MJB3)
  - Direct laser writing & Photomask preparation (Heidelberg Instruments DWL-66)

- **Thin film deposition/etching CHARACTERIZATION**
  - E-beam deposition (VST, Edwards 306E)
  - Thermal evaporation (VST)
  - RF sputtering (MRC)
  - DC sputtering (Penta Vacuum)
  - RIE Etching (Unaxis)
  - DRIE etching (Unaxis)
  - Wet etching
  - Wet and dry Cleaning

- **Measurements**
  - Profile/Step height (Tencor, Veeco)
  - XRF (Jordan Valley)
  - Spectroscopic Ellipsometer (Woollam M2000DUV)
  - Spectroscopic Reflectometer (Sentech FTP)

- **Backend**
  - Dicing (K&S 982)
  - Wire Bonding (K&S)

Customers

Companies

- Al Cielo Ltd.
- Applied Materials Israel
- Cell Kinetics (Medisel)
- CI Systems
- Compass
- El-Mul Technologies
- EL-OP Ltd.
- Flamingo Electronics
- IAI
- Nova
- NOVAMEDES
- Orbotech
- RAFAEL
- TeraOP
- Tessera Israel
- TEVET

Academia

- Bar Ilan University
- Ben Gurion University
- Hebrew University
- Technion
- Weizmann Institute

Contact

Mark Oksman
Email: Oksman@eng.tau.ac.il
Phone: 03-6407926

http://www.tau.ac.il/~nanotau/Fabrication.html
Major items that were purchased or installed in 2008 include:

**PPMS – measurement station.**
This system is an important research tool for transport measurement in low temperatures and strong magnetic fields. It supports research in nano-electronics in general and particularly in research focusing on nanomagnetics and nano-ferroelectrics as well as nanosuperconductivity. The system is installed in the new Laboratory for Nanosystems at Low Temperatures.

**Visualization and analytical characterization of biological nano systems (600k$).**
This system serves a large group of researchers from the faculties of Life Sciences and Medicine. It is capable of visualizing tissues at a cellular resolution for the purpose of drug targeting. In particular, this system enables us to monitor cells labeled with nanoparticles. The system is installed in the Faculty of Medicine equipment center.

**NIL – Nano imprinting lithography (630k$).**
This tool allows for patterning nanostructures on hard and soft materials using stamps. TAU’s nano-imprinting system will be the first to be purchased and used in Israeli academia. The system will be installed in the clean rooms of the Nano-center.

Additional equipment which was promoted by the TAU nanocenter includes:

- The establishment of the Laboratory for Microscopy and Electrical measurements in biological systems.
- Support for ultracentrifuge analysis and sorting of organic, inorganic, and biological nanoparticles as well as proteins. The ultracentrifuge is intended to serve mainly the Faculties of Life-sciences and Medicine as well as the Chemistry department.
- Due to its prospects in nanoscopy, the center has supported the purchase of a University confocal microscopy lab (Faculty of Medicine) including a 2-Photon confocal microscope system.
- We have upgraded our ability to manipulate and measure transport of individual nano objects in parallel with observing them in our environmental SEM.
- The nanocenter has also supported, through “C”, the refurbishing of several systems such as the Penta-Vacuum DC/RF sputtering system. The newly purchased PECVD system is in the final stages of installation.
Over the past several years we have outlined four thematic topics to be the focus of our scientific activity. The goal of the nanocenter is to promote and support these topics with the aim of achieving a critical mass of activity in these areas.

**Renewable energy**

New battery technology and energy harvesting schemes as well as improved photovoltaic methodologies are among the goals of the Nanocenter’s renewable energy research program. Prof. Peled and Prof. Golodnisky’s (Chemistry) research is at the forefront of battery and fuel cell technology. Dr. Richter (Chemistry) and Prof. Carmeli (Life Sciences) innovated a unique solar cell. Dr. Scheuer, Prof. Boag and Dr. Hanein (all from Engineering) participate in a new nano-antenna project. Prof. Patolsky’s research has produced new technologies in nano photovoltaics and fuel cells. Dr. Selzer (Chemistry) and Prof. Patolsky (Chemistry) are investigating nano-related thermoelectric power.

The work is progressing well scientifically as is reflected by three related industry contracts. We have invested in equipment infrastructure to further promote this activity.

**Bio-Physical interfacing**

This topic encompasses the study of cell-substrate interaction at the nanoscale, utilization of nano-elements to interface with cells and the construction of novel bio-chips and bio-sensors. This activity is marked by strong collaboration between researchers from the various faculties on campus. This is a prime example to the impact of the nano-center in promoting and nurturing multidisciplinary activity.

Currently, noted activity includes: Prof. Patolsky’s (Chemistry) nanowire based sensors; Dr. Hanein’s (Engineering) carbon nanotube interfaces; The newly developed method of surface wetting properties by electron bombardment of dielectric surfaces, developed by Prof. Rosenman (Engineering) is explored as a new tool to control cell-surface adhesion. Collaboration between Prof. Rosenman and Prof. Gazit (Life Sciences) utilizes vacuum deposition techniques to deposit biological, polymer material onto surfaces with the aim to control surface wetting properties. Prof. Shacham-Diamand and Prof. Nathan from the school of electrical engineering are interested in bio-chips. Recent initiated collaboration between Dr. Hanein and Prof. Cheshnovsky (Chemistry) in collaboration with HUJI researchers, Prof. Banin and Prof. Yitzchaik, aims to use nano-approaches in order to realize an artificial retina.

This year, in accordance with last year’s plan, we have established a new laboratory for optical and electrical measurements on bio-nano systems. This lab will serve as a basis for a more comprehensive Bio-nano research laboratory.

**Magnetism, superconductivity and ferroelectricity**

This topic encompasses nano-magnetics, nano-ferroelectrics and nano-superconductivity. Research in this field is currently conducted at the School of Physics, School of Chemistry and the Faculty of Engineering with strong interfaculty collaborations. A few new notable activities include: new methodologies of electrode-less deposition of magnetic alloys, a significant contribution to magnetics MEMS efforts, by Prof. Shacham-Diamand (Engineering) and Prof. Gileadi (Chemistry); Dr. Dagan’s (Physics) and Dr. Richter’s (Chemistry) research toward modifying the properties of superconductors, using self assembly monolayers; Dr. Markovich (Chemistry) synthesizes magnetic and ferroelectric nano-crystals, characterizes them and investigates various enhancement methods and applications; Prof. Cohen (Chemistry) and coworkers plan to exploit these nano-crystals for imaging.

The infrastructure for this activity has been dramatically enhanced by the establishment of a new lab. This
recently established Laboratory for Nanosystems at Low Temperatures includes the newly acquired PPMS system and a SQUID magnetometer. It will serve as a public research laboratory in nano-magnetism, and nano-superconductivity.

**Nanoscopy**

Recently, a new topic was added to the three outlined above. With the recruitment of Dr. Yael Roichman we have reached a critical mass in nanophotonics and nanoscopy. Dr. Yael Roichman (Chemistry) specializes in holographic optical tweezers which serve as a strong tool in the field of nanoscopy. Ongoing activity includes the research conducted by Dr. Scheuer (Engineering) on nanophotonics, Prof. Cheshnovsky (Chemistry) on the spectroscopy of nanoparticles and nano-junctions, and Prof. Mendelovic (Engineering) on photonic crystals.
In recent years an increasing number of physicists are focusing their attention on interesting physics found in biological and chemical systems in the nano scale. This branch of condensed matter physics is called "soft condensed matter" and aims at providing better understanding of biological and chemical systems, processes and materials. We study theoretically physical properties of biomaterials and macromolecular materials such as proteins, DNA and other polymers. Most of these water soluble polymers and macromolecules are charged. Hence, special attention is paid to the inter-relation between their electrodynamical properties and their structural ones. We mention now several specific projects which are investigated in our group.

i) Recent works involved new models to estimate the stiffness of charged macromolecules and its affect on the molecular conformation in aqueous solutions.

ii) The adsorption of charged polymers onto oppositely charged surfaces is explored and results from a competition between electrostatic attraction to the charged surface and loss of entropy.

iii) We study heterogenous macromolecules such as polymer chains composed of several distinctive blocks (sub-units). Because the blocks have different physical properties, they induce morphological changes and transitions. Recently, the response of such systems to electric fields was explored.

References:
Fighting bacteria using man-made Nano Particles

Today, there are an alarming increasing number of strains of disease-causing bacteria that can resist multiple drugs; bacteria are clearly capable of developing antibiotic resistance at a higher rate than scientists can develop new drugs [1]. To reverse this course of events, we have to develop novel strategies to fight them.

We developed a new strategy of based on specially designed nano particles that have both hydrophobic and hydrophilic sites. These particles can both temper bacteria communication and even paralyze directly the individual bacteria as shown in the attached figures [2].

Formation of networks of nano-bubbles in water using weak RF signals

It is known that weak RF signals can have long time effect on water. We have shown the effect on electrochemical deposition and on the growth of bacterial colonies [2]. Understanding the mechanism of this phenomenon can serve the basis for many new applications. Together with Prof. Aharonov, we investigate the idea that the effects are the outcome of the formation of networks of nano bubbles (networks with long range orientation correlations).

DNA-based Nano Electronics

We perform theoretical studies of the propagation of both charge and excitonic solitons along DNA molecules. These theoretical investigations led to a patent of DNA-based single electron tunneling transistor. We emphasize that unlike other studies in which the DNA molecules are used as templates, in our approach the transistor “head” is made of DNA molecules [3] as is shown in the figure below.

References:
Electron-doped cuprates offer a unique laboratory for studying a variety of phenomena such as: superconductivity, quantum criticality, density waves. While the undoped material is antiferromagnetic upon adding charge carriers the material becomes superconducting. It is not clear whether these orders coexist and on what scale. We perform local and macroscopic tunneling study to clarify these issues that are eminent for understanding superconductivity in the cuprates.

Research
Materials in which electrons are strongly interacting with each other exhibit variety of exotic properties such as: high temperature superconductivity, colossal magneto-resistance, ferroelectricity, magneto-electric effects in multiferroic materials. Examples for such materials are: cuprates, manganites, ruthenates, and many more. Generally speaking, small stimulus results in a large change in one or more physical property.

In our laboratory we are studying the electronic structure and the nature of the phase transitions of such materials by tuning control parameters such as chemical doping, epitaxial strain, external fields etc. Of particular interest is the influence of sample dimensions and interfaces with other correlated systems on its physical properties.

Current research topics are:

i) Superconductivity on the nanoscale
Superconductivity is a macroscopic quantum phenomenon. However, when the superconducting specimen is constituted of weakly connected nano-grains many interesting physical phenomena occur. In our laboratory we are able to probe superconducting fluctuations and their dependence on the nanostructure of the sample.

ii) Interface effects between insulating perovskites
It has been found that when two insulating nonmagnetic perovskite form an epitaxial interface this interface can become highly conductive, magnetic and even superconducting. Using our laser deposition facility we are trying to produce and study such interfaces.

iii) Local and macroscopic orders in electron-doped cuprates
Electron-doped cuprates offer a unique laboratory for studying a variety of phenomena such as: superconductivity, quantum criticality and density waves. While the undoped material is antiferromagnetic upon adding charge carriers the material

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References:
Nanoscale magnetic systems
b) Giant magnetoresistance (GMR) and tunneling magnetoresistance (TMR).
c) Extraordinary Hall effect in ultra-thin films and heterogeneous mixtures.
d) Magnetic properties of single nanoscale magnetic clusters and their arrays.
c) Development of new experimental techniques for nanoscale magnetometry, with a special emphasis on the extraordinary Hall effect technique.
d) Development of new magnetic field sensors and memory devices based on the extraordinary Hall effect.

Heterogeneous superconducting systems
a) Localized superconductivity and insulator – superconductor transition in granular superconductors.
b) Superconducting fluctuations above and below the metal-insulator transition.
c) Proximity effect in superconductor – normal metal and superconductor – ferromagnet mixtures.

References:
A nanoscale coherence length is a key property of high temperature superconductors. Point Contact and STM spectroscopy can be used to reveal the effect of nanoscale faceting on the order parameter (1,2). These studies are fundamental for the development of tunneling and Josephson devices. Another kind of device being studied consists of a two ferromagnetic nanowires connected to a superconducting base. They allow in principle to propagate the two electrons of a Cooper pair in physically separate channels, which can form the basis for producing entangled states for quantum computing (3). In these devices, the distance between the two ferromagnetic wires must be in the nanometer range. Another field of study is that of composite metal/insulator mixtures, which behave as three dimensional arrays of weakly coupled metallic nanodots. Transport properties in these structures are extremely sensitive to the composition, they range from metallic to insulators, and can even be super-insulators when the metallic grains are superconducting due to the opening of the energy gap (4). They are model systems for the study of very low superfluid density condensates.

References:
2. Local and microscopic tunneling spectroscopy of YBaCuO films: evidence for a doping dependent is or idxy component in the order parameter.

Two oppositely spin-polarized contacts with barriers $Z_1$ and $Z_2$, at a small distance $l$. Crossed Andrew reflections (CARE) are represented. Perturbation of the superconducting gap occurs in the hatched regions.
With recent advances in nanotechnology, state-of-the-art nanoelectromechanical systems (NEMS) can now be fabricated with lateral dimensions down to a few tens of nanometers and combined with self-assembled nanostructures such as nanowires and carbon nanotubes, achieving normal frequencies that exceed 1 GHz. As a consequence, NEMS are no longer simply smaller and improved versions of MEMS (microelectromechanical systems), but also offer great opportunities for the study of mechanics in physical regimes that previously had been inaccessible experimentally. The Lifshitz group—working in collaboration with the lab of Prof. Michael Roukes and the theoretical group of Prof. Michael Cross, both at Caltech, as well as the lab of Dr. Eyal Buks at the Technion—is concerned with the theoretical study of nanomechanical systems, covering a broad range of questions as listed below.

**Research projects in nanomechanics:**
1. **Mesoscopic phonon transport** — Transport of mechanical energy (heat) through nanomechanical systems, with emphasis on the behavior of ballistic phonons [1].
2. **Dissipation of energy in nanomechanical resonators** (beams, cantilevers, nanotubes, etc.) [2].
4. **Quantum electromechanics** — studying the possibility to observe quantum-mechanical behavior with nanomechanical devices [6].

The Lifshitz group is also involved in unrelated theoretical research in the field of quasicrystals. In collaboration with Prof. Ady Arie, of the Faculty of Engineering, Lifshitz is studying how to exploit nonlinear photonic quasicrystals for the purpose of optical frequency conversion [7,8]. In collaboration with Prof. Mordechai Segev of the Technion, Lifshitz is studying the dynamical properties of optically-induced nonlinear photonic quasicrystals [9,10].

**Selected References:**
**Prof. Alexander Palevski**  
**Physics**

Quantum Transport in Nanostructures

**One-dimensional quantum wires**
Electronic transport properties were studied at low temperatures in V-grooved quantum wires. The quantization of the conductance as a result of one-dimensional band structure was observed. The role of the inter-subband scattering was elucidated. The value of the interaction constant for GaAs was deduced from the Luttinger model.

**Superconductor proximity effect in ferromagnetic junctions**
The oscillations of the critical current were observed for the first time. The theory based on the formation of the $\pi$-junction in Josephson coupled structures containing ferromagnetic layers was verified.

**Neuronal Networks (in collaboration with the group of Prof. E. Ben Jacob)**
We have lithographically fabricated and studied *in vitro* neuronal networks. The networks exhibit scale invariant Levy distribution and long-range correlations.

References:

The above figure shows quantum nano-wire device: (a) SEM micrograph of the wire grown on prefabricated V-grove substrate of GaAs with the gates. (b) schematic drawing explaining the special separation between 2-dimensional and 1-dimensional regions
Light, tunneling junctions and nanoparticles:
In this project, we study the correlation between the electrical properties and the optical properties of isolated nanocrystals or polymeric films. The sample, deposited on a surface, will be studied using scanning Tunneling Microscope (STM). The transport properties of the sample will be measured using I-V spectroscopy. In parallel, on the same particle, light emission induced by inelastic tunneling will be monitored. A dedicated STM head is coupled to a high collection efficiency mirror developed for this project. A major virtue of the project is that the optical and electrical measurements will be performed on the same single isolated nanoparticle. In case in which the particle is inhomogeneous, different light emitting parts are differentiated. The same methods will serve in studying the relation between the morphology segregation and light emission in multichromophor polymeric films.

Clusters and photoelectrons:
The long controversial problem, of a critical size in which clusters of bivalent metals approach band-gap closure (metallic behavior), was addressed by us. By using PES of negatively charged clusters we showed that the band gap closes at the cluster-size of ~400 atoms. At smaller sizes mercury clusters behave as semiconductors with band gap varying for 3 eV (Hg4) to 0.2 eV (Hg280). Electron-hole pairs could be efficiently excited in semiconductor mercury clusters. Their thermalization and recombination via Auger electron ejection is the focus of our current research. The understanding of the dynamics of these processes may offer ways to improve the performance of semiconductor based nano-devices.

References:
Complex fluids, or soft matter, is a general term referring to a broad class of materials, which are neither molecular liquids nor atomic or molecular crystals. Examples include surfactant solutions, polymer solutions, interfacial monolayers, membranes, suspensions, and liquid crystals. The rich phase behavior and dynamic response of such materials stem from the existence of inner structures on an intermediate, nanometer-to-micron scale between the molecular and the macroscopic scales (e.g., micelles, colloid particles, polymeric structures). The theoretical challenge is to account for the emergence of these structures, their effect on material properties, and their various instabilities.

In the past several years we have been focusing on the dynamics and flow properties of complex fluids, and on various effects caused by micro- and nano-scale confinement. Recently studied systems have included: (a) colloid suspensions in narrow channels; (b) particle-encapsulating vesicles; (c) fluid membranes with embedded proteins; (d) compressed surfactant monolayers; (e) surfactant aggregates (micelles); (f) membrane stacks (lamellar phases).

References:
Over the past decade, research in the field of fullerene chemistry has greatly increased due to a wide range of potential applications proposed for fullerene-based materials. These applications span non-linear optical properties, superconductivity and the biological activity and, as industrial scale of fullerenes production approaches multi-ton level per year, the human and environmental exposure to the carbonaceous nanomaterials will be undoubtedly increased. While most of the current research is focused on examination of tissue- and cell-level nanomaterials influence, interaction on a molecular level, with native proteins, remains mostly unexplored.

As current research related to the toxicological and environmental effects of carbonaceous nanomaterials is still in its infancy, there is a rapidly growing public concern regarding the potential impact of these nanomaterials on human health and on environment. We believe that our research is very important as it lays a foundation for better understanding of carbonaceous materials bio-delivery systems and potential effects of these nanomaterials on environment and on human health. In addition we wish to understand how these compounds are interacting on molecular level with various native proteins and other biomolecules. Not less fascinating are the potential applications of these hybrid materials as crucial components in the future nano-bioelectronic devices, nanosensors and artificial organs, functioning as the biocompatible interface between biological and electronic systems.

References:

(Left): Proposed by docking algorithm location of the [Cn] fullerene ligand (red) inside BSA protein, relative to position of the Trp214 residue (blue). (Right): MALDI-TOF MS spectrum of purified BSA-[C60]-fullerene complex.

Dr. Michael Gozin  Chemistry
Formation and Characterization of Stable Protein Complexes with Fullerene and its Derivatives

Tel: (972)-3-6405878
Fax: (972)-3-6405879
Email: cogozin@post.tau.ac.il
Personal Website: www.tau.ac.il/chemistry/gozin/
nanoscience and nanotechnology open a unique opportunity for the application of highly accurate theories to realistic material science problems. The research in my group focuses on the theoretical study of the mechanical, electronic, magnetic, and transport properties of systems at the nanoscale. Using first-principles computational methods, we aim to characterize both ground state and dynamical properties of such systems. A combination of codes developed within our group and commercial computational chemistry packages, operating on a highly parallelizable high-performance computer cluster, allows us to address the properties and functionality of a variety of systems ranging from carefully tailored molecular structures up to bulk systems. On top of basic science questions, the design of technologically applicable nanoscale material properties for future applications in fields such as nano-electronics, nano-spintrons, accurate and sensitive chemical sensing, and nano-mechanical devices, is being pursued.

References:

Single molecule techniques offer a unique tool to study in real-time the dynamical behaviour of individual molecules and provide the possibility to construct distributions from individual events rather than from a signal stemming from an ensemble of molecules. In biological systems, known for their complexity, these techniques make it possible to gain insights into the detailed spectrum of molecular conformational changes and activities. In collaboration with experimental groups in Europe we observed a single enzyme reaction for extended periods of time (hours), using confocal fluorescence microscopy. When adding a profluorescent substrate the monitored enzymatic activity appeared as a trajectory of on-state and off-state events. The waiting time probability density function (PDF) of the off-state and the state-correlation function fit stretched exponentials, independent of the substrate concentration in a certain range. In addition, clusters of fast events were detected in the ordered off waiting times trajectory, indicating correlations in the activity. Our findings imply that a fluctuating enzyme model, which involves a spectrum of enzymatic conformations that interconvert on the timescale of the catalytic activity, best describes the observed enzymatic activity. The “text book” Michaelis–Menten scheme has been modified accordingly.

References:
The group uses various colloidal chemistry methods to prepare inorganic nanocrystals, mostly of functional oxides or noble metals, and study their magnetic, optical, magneto-optical and magneto-resistive properties. The Langmuir-Blodgett technique is used by the group to prepare ordered close-packed monolayers of magnetic nanocrystals. Spin polarized transport is studied in Fe$_3$O$_4$ nanocrystal films in various types of nanoscale devices and by scanning tunneling spectroscopy. The magnetic properties of these monolayers as well as multi-layer films were studied to learn about various physical aspects of such arrangements of strongly interacting superparamagnetic particles, especially with respect to the magnetization freezing transition. Another study on magnetic nanocrystals focuses on defect induced ferromagnetism in non-magnetic oxide nanocrystals, such as HfO$_2$. Nanocrystals made of ferroelectric materials such as BaTiO$_3$ are also currently being studied using electron holography, which is capable of imaging the internal polarization fields in the nanocrystals and by this open a new window into the largely unknown world of nano-ferroelectrics.

Another field of research is the combination of chirality and surface plasmons of colloidal noble metal nanoparticles. The group has recently demonstrated the resonant enhancement of absorption and circular dichroism in chiral molecules attached to silver nanoparticles.

In another project, wet colloidal chemistry techniques for the growth of metallic nanowire arrays on surfaces are being developed. A recent development of a preparation of mixed gold-silver nanowires in a thin surfactant solution film on a substrate led to the formation of very thin (3-5 nm thick) and micrometer long nanowire networks which posses metallic conductivity and are highly transparent.

References:
My research effort in the past few years has focused on particular types of interfacial systems and processes - those encountered in the evolving field of Molecular Electronics. The possibility that molecules and small molecular assemblies can replace conventional conductors and semiconductors in nano-scale electronic devices has become a subject of intense discussion. The new fundamental issues associated with such systems - the electronic structure, the charge transfer properties, energy transfer and relaxation and the capacitive properties (to name just a few), of molecules connected to conducting leads, present new theoretical and experimental challenges. Recent studies in our group aim at developing theoretical and numerical tools to study electron transmission through such interfaces. A recent series of papers that focus on the electron transmission properties of water, arguably the most important electron transmitting medium, has demonstrated a new resonance effect that explains the observed high efficiency of electron transmission through this medium. More recent work has focused on analyzing the crucial issue of thermal relaxation and heating effects as well as heat conduction in molecular conductors that bear on the question of thermal stability of such systems, and on developing a theoretical framework for understanding inelastic tunneling features and phonon induced non-linear response of molecular conduction junctions. Our current studies aim at analyzing the possibility to probe and control of molecular junctions by light.

References:
Nanoscale science holds extraordinary promises to impact crucial issues of our era, such as improved medical diagnosis and treatment, renewable energy, more efficient information technology, and environmental protection. My research interests are concerned with ‘multifunctional’ systems of reduced dimensionality, and their applications for addressing important chemical, biochemical, physical and technological problems. Specifically, the research will focus on the synthesis, characterization of the fundamental physical and chemical properties, and applications of integrated nanostructured materials that combine tuneable optical, electrical and magnetic properties, as well as the study and understanding of the mutual interactions between light, electricity, and magnetism at the nanometer scale. A major goal of this research is to address the "structure-function" relationship, as one of the most basic and central questions in materials chemistry. A second and more central aspect of the research concentrates on the application of nanowire-based electronic/optical devices in the biological and chemical detection area, with the aim to explore and exploit the nano-scale potential advantages in answering ‘open questions’ in biology.

References:
n our group, four projects are related to nano science and technology. We have developed a nano-porous proton-conducting membrane with a typical pore size of 1.5 nm. On the basis of this membrane we have developed a direct methanol fuel cell and a direct ethylene glycol fuel cell which, at time of writing, have demonstrated the highest recorded power densities (0.5 and 0.32 W/cm² respectively). We are studying synthesis routes for highly active nano-size platinum-alloy catalysts (2-5 nm in size) for use in hydrogen and in alcohol fuel cells (in collaboration with Prof. Golodnitsky). We have developed and demonstrated the first on-chip three-dimensional thin-film lithium-ion microbattery (collaboration with Prof. Golodnitsky and with Prof. Nathan of the Faculty of Engineering). In collaboration with Prof. Golodnitsky, Prof. Scrosati (Rome) and with Prof. Wieczorek (Warsaw) we have developed and characterized a single-ion lithium polymer-electrolyte conductor using anion nano traps.

We were the first to develop a procedure for orienting the helices of poly ethylene oxide (PEO) in the orthogonal direction by casting the film under magnetic field (MF), the result of which is a one-order-of-magnitude increase in polymer electrolyte (PE) conductivity and a similar decrease in PE/lithium electrode interfacial resistance (in collaboration with Prof. Golodnitsky).

References:


SEM images of cross-section of the LiI-P(EO)3 9% γ-F22O3 (8nm) electrolyte typically cast (a) and cast under a magnetic field gradient (b)

Tel: (972)-3-6408438, (972)-3-6414126
Fax: (972)-3-6409293
Email: peled@post.tau.ac.il
Personal Website: www.tau.ac.il/chemistry/moreinfo/peled/
Dendrimers are branched, highly ordered macromolecules that are assembled in a modular, iterative fashion from polyfunctional building blocks. The results of the process are not only aesthetically appealing but offer chemists three-dimensional structures of nanometer-range size with a variety of interesting architecture-dictated properties for a wide spectrum of applications. The modular mode of assembly and highly ordered nature of dendrimers make them especially suitable for the building of nanoscale devices. During the past few years, my group actively pursued the preparation of dendritic molecules on insoluble support as a platform for the generation of highly active and selective heterogeneous catalysts. To date, very few dendrimers have been prepared on solid support. We developed an efficient synthesis of new poly(arylbenzylether) dendrons on solid polymer support, functionalized their termini with catalytic units and explored their properties. An unprecedented positive dendritic effect on the Pauson-Khand intramolecular annulation was discovered when cobalt complexes of this dendrimer were used as reaction catalysts. An even more dramatic effect was demonstrated with poly(arylbenzyl-ether)-dendrons for Pd-catalyzed Heck and Suzuki processes. Recently, we began exploring dendrimers as platforms for diagnostic agents for molecular imaging.

References:
Structure of nanomaterials
The development of atomistic models to study structural properties of semiconductor nanocrystals and carbon nanotubes is one of the major subjects of my research. We were the first to develop an atomistic force-field model for semiconductor nanocrystals. Our model was used to explain the coverage of the different facets of the nanocrystal and the preferential growth of nanocrystals to nanorods.

Self-assembly of nanoparticles
We developed an integral equation theory to study the interactions between nanoparticles in solutions and more recently we developed a lattice-gas model to study drying mediated self-assembly of nanoparticles. Our approach lays down the theoretical foundation of dynamical assembly of nanoparticles in 2D and 3D.

Optical and electronic properties of nanomaterials
Another focus includes the study of electronic and optical properties of semiconductor nanocrystals and other low dimensional quantum structure. Our focus was mainly devoted to understand the role of the environment on these physical properties. We have been involved in the development of novel algorithms to solve the electronic structure of such large systems.

Conductance and magnetoresistance in 1D structures
Using analytic continuum models and atomistic empirical calculations we have shown that relatively small magnetic fields are required to control the current through a nanoring, despite the fact that a ring at the nanoscale captures only a small fraction of the magnetic flux.

References:
The Bio and Molecular electronics group was founded in 2003. Our main focus is on construction and electrical characterization of novel organic and bio-molecular thin films and monolayers. On going projects:

(i) Construction and characterization of molecular and bio-photonic based devices Recently we constructed a working electronic device based on a vertical configuration, which consists of organic molecules and Photo-System I based nanoparticles adsorbed in a self assembled fashion between a bottom gold electrode and a top palladium or ITO layer (Figure 1). Our prototype molecular device which was synthesized by Dr. M. Gozin from TAU showed unique coulomb staircase and negative differential resistance properties at room temperature.

(ii) Film Formation From Dipeptide Nanotubes
In this research project we present a novel method to produce a new family of films based on the controlled organization of diphenylalanine dipeptide nanotubes. Peptide-based nanotubes provide a new building block for bio-nanotechnology, via self-assembly processes. Such nano-templates can be controlled to produce films that present well-ordered self-aligned properties, and well-defined geometrical structure with nucleation centers and grain boundaries. This new family of films has been produced via control over the inter-molecular interactions between the nanotubes, and control over the polymerization process that is responsible for the construction of the film.

References:
2. N. Verleger, N. Rosenberg, M. Gozin, S. Richter, Influence of Junction-containing Alkanethiols on Schottky Barrier Height at the Hg/WSe2 Interface, submitted for publication.
Our group uses holographic optical tweezers in two different modes: we study interactions between microscopic objects that lead to organization, and we construct prototype materials and devices to address the technological issue of which materials and devices should be built.

Holographic optical tweezers (HOTs) use computer generated sequences of holograms which create dynamic arrays of optical traps. One direct application of HOTs is the manipulation of colloidal particle and their organization into interesting structures. We use the HOTs to construct new complex materials with optical properties such as metamaterials and photonic bandgap materials. Using several traps to manipulate a single particle enables us to trap, transport, fuse and cut non-spherical objects such as nanowires.

A more sophisticated approach uses the holograms to change the mode of the laser light, generating potential landscapes which both trap and drive colloidal particles. These potential landscapes serve to create simple model systems in which organization in far-from-equilibrium conditions can be studied.

References:
The research in my group strives to construct measure and understand the physics and chemistry of single molecule electrical junctions. This research is crucial for the advancement of future nanoelectronic devices. Current research in the group is divided into two areas:

1. Measurement of the thermophysical properties of molecular junctions such as thermovoltage, and heat conduction. Understanding heat conduction through molecular junctions is important as heat capacity of molecules is extremely small as a result heat dissipation in molecular junctions is expected to drastically affect their stability and performance.

2. Molecular spintronics: Theory suggests that the tunneling magnetic resistance (TMR), i.e., the efficiency of spin tunneling without flipping, in molecular junctions could be as high as 500%, while standard solid state devices are operating at 40%. Experimental verification of this prediction is underway. Highly efficient TMR elements will enable to develop universal ‘on-chip’ memory technology. Since typical energy scales of molecules are in the optical and infrared regime, where today’s laser technology provides a wealth of coherent light sources, future research in my group will focus on the various ways by which lasers could be used to affect and direct currents through single molecule junctions.

References:
Professor Yoram Shapira aims at redirecting microelectronics to integrating new functions into the conventional microprocessor chip. Integrating mechanical, optical, chemical and biological technologies unto multi-functional chips will enable them not just to “think” but also to sense, see, act and communicate with their operators, possibly within our bodies. There they can be utilized as micro-laboratories and biosensors as well as interact with bio-systems diagnostically, therapeutically and perhaps surgically.

Other fields of interest aim at getting complete understanding of carrier transfer via a molecule or a molecular film at the semiconductor/organic interface implies understanding of: (1) the nature of the molecular levels relevant to charge transfer into the semiconductor and transport through the molecular film, (2) the nature of the chemical and electronic interactions between the molecule and the surface and (3) the impact of molecular structure, i.e., of molecular orientation and order, and of neighboring molecules on the electronic structure of the semiconductor surface. This research is aimed at addressing these problems by conducting a parallel experimental and computational effort. Current activity is directed towards studies of nanometer scale high-K oxide layers for 65-nm-design-rule transistors. The physical properties and reliability implications of these layers and their semiconductor interfaces are investigated. The results of the preceding projects will be implemented in applied programs for in-vivo drug delivery systems as well as distributed information-gathering micro-arrays.

References:
Pulsed air arc deposition of carbon nano-tubes (in open air, on room temperature substrates).
Submerged arc synthesis of nano-particles
Directed growth of nano-structures using an imposed electric field
Nano-structured thin films and coatings for improved mechanical properties

References:

"Forest" of erect multi-wall carbon nano-tubes deposited on a Ni-coated glass substrate at room temperature in open air, by a single 20 µs arc discharge.

Tel: (972)-3-6407364
Fax: (972)-3-6410189
Email: boxman@eng.tau.ac.il
Personal Website: www.eng.tau.ac.il/~boxman/index.html
Dr. Noam Eliaz Engineering

From Biomaterials to Space, from Hydrogen to Hydroxyapatite

Dr. Noam Eliaz has been involved in several projects related to Nano Science & Technology. These projects are consisted of both experimental and modeling work. Firstly, an MSc student (M. Eliyahu) used electrochemical atomic force microscopy to study in situ and ex situ the processes of nucleation and growth as well as the microstructure of hydroxyapatite electrodeposited on titanium for biomedical applications. Electrodeposition of hydroxyapatite was shown to result from precipitation in solution, following two stages: (1) instantaneous nucleation, two-dimensional growth; (2) progressive nucleation, three-dimensional growth. Secondly, in a joint work with Soreq NRC, a model was developed to describe the processes involved in the irradiation of solid targets by femtosecond laser pulses and to predict the optimal target and laser parameters for efficient nanoparticles synthesis. Aluminum and carbon nanoparticles/nanotubes were then successfully synthesized and characterized by several analytical techniques. Thirdly, also in collaboration with Soreq NRC, an MSc student (R. Verker) constructed a laser-driven flyer ground simulation system and used it to accelerate aluminum flyers to impact velocities as high as 2.9 km/s against Kapton films with different thicknesses, thus simulation hypervelocity space debris impacts at low-Earth orbits. Impact effects on the internal structure of the polymer were studied by means of X-ray microtomography. Currently, the work is being extended as a PhD work in which synergistic effects of space environment on durability of hybrid nano-composites will be studied. Fourthly, an MSc student (V. Kalmanovich) modeled the diffusion of hydrogen in various metallic glasses under different conditions of short range order and diffusion paths. Both curvature of the Arrhenius plot and an inverse Arrhenius law were observed. The effect of alloying elements on the activation energy of hydrogen diffusion was evaluated in terms of their electronic structure and mean volume per atom.

References:
Dr. Goldfarb is mainly interested in self-assembled and self-organized growth of epitaxial nanostructures inside STM. One way to self-assemble nanostructures is to introduce strain into the growing layer by carefully controlling the mismatch between the crystalline lattices of the layer and the substrate (heteroepitaxy). In other words, relaxation of this strain drives the self-assembled formation of nanocrystal arrays, which can be used in quantum-dot and -wire devices, provided the size and shape distribution of the nanocrystals in the array is sufficiently narrow, and their degree of crystalline perfection is high. Since these characteristics in self-assembled nanocrystals are thermodynamically and/or kinetically determined, only deep understanding of these tendencies (that occur naturally during growth) can provide the means to control them and perhaps even tailor-on-demand. Therefore, the projects carried out in the laboratory are aimed at exploring epitaxial materials systems with varying mismatch, such as Ge/Si [1] (see the figure below), Ti/Si[2], Fe/Si [3], Co/Si [4], etc., in order to produce some generalized model(s), and the ability to achieve degree of understanding and control sufficient for implementation in real devices. One of the strengths of the laboratory is the rare ability to observe the evolution of the growing epilayers in real-space and -time by STM, due to state-of-the-art UHV SPM Microlab where the deposition flux is incident upon the sample while it is being scanned and continuously imaged during growth.

References:
Our research is focused on developing novel micro and nanofabrication techniques and systems. Our main interest is in systems for biological applications. In the last several years we have developed a novel class of carbon nanotube (CNT) based micro electrodes, specifically designed to interface with neuronal systems. The enhanced electrochemical properties of the electrodes, their flexible and simple micro-fabrication preparation procedure as well as their bio-compatibility and durability suggest that carbon nanotube electrodes are a promising platform for high resolution capacitive electrochemical applications.

A second theme of our research concerns with a novel approach of patterning cultured neural networks in which a particular geometry is achieved via anchoring of cell clusters (tens of cells/each) at specific positions. Compact connections among pairs of clusters occur spontaneously through a single non-adherent straight bundle composed of axons and dendrites. The approach can be used to build advanced Neuro-chips for bio-sensing applications (e.g drug and toxin detection) where the structure, stability and reproducibility of the networks are of great relevance.

A third theme of our research is geared towards the realization of devices consisting of well ordered single walled carbon nanotubes. A newly developed method, we recently demonstrated, establish the means to achieve precise positioning of these tiny elements in a manner suited for the production of useful, commercial devices.

References:

Neuronal cells on a small, high density CNT island and CNT based chip for recording and stimulation of neuronal systems.
The research activity in Prof. Mendlovic Lab deals with silicon nano-photonic devices for telecommunications applications. The main objectives of the research are design and fabrication of highly efficient passive devices and application of dynamic properties using different physical phenomena and materials. Currently we are working on three projects. The first is tunable optical filters based on 1D photonic crystal (PhC) cavities. In this project we design high quality passive cavities that form a shaped filter then use thermal modulation to tune the filter’s center frequency. The second project is about producing ultra fast EO modulators using 2D PhC cavity. In this project we compare two different methods of modulations (both use carrier injection) and optimize each system both in optical design and material design. In the third project we design and fabricate a tunable Dispersion Compensator Based on ring resonators.

As part of our research activity we have developed a fabrication process as well as a suitable test system so we are able to get experimental results. Our results so far include the design of a novel ultra small beam-splitting waveguide junction, design and fabrication of high-Q 1D PhC cavities and fabrication of 2D PhC waveguides. In the future we intend to expand our research to other fields such as incorporation of CNTs on the optical silicon chip.

References:
2. Damian Goldring, David Mendlovic, “High quality 1D Photonic Crystal cavity for optical filters” – to be published
3. Damian Goldring, David Mendlovic, “Tunable nano-photonic optical filters” – to be published
Prof. Gil Rosenman  Engineering

Ferroelectric nanodomain polarization reversal and development of new generation of nonlinear photonic devices

Studies of nanodomain reversal effect in ferroelectrics

Fig. 1 (Top): Nanometer scale domain structures tailored using HVAFM for (a) nonlinear 2-D nonlinear optical converter (domains 1x1 mm); (b) domain grating with period 410 nm for optical coupler (c) domain grating with period 500 nm for UV laser

Fig. 2 (Bottom): 2D nanometer scale domain structures of tailored different symmetry using IEB method in LiNbO3, for nonlinear photonic devices

Wettability engineering of Hydroxyapatite bionanoceramics by surface potential modulation method. The variation of contact angle is in the range 10-100°. Such a wettability modification allows effective immobilization of various biological cells

Studies of physical properties of biological and biomimetic materials in nanometer scale

References:
4. G. Rosenman, E.Weinbrand, "Ferroelectric domain reversal by indirect charged particle beam", Provisional Patent, November, 2004
Prof. Yossi Rosenwaks  Engineering

Nano probing, Electrical Measurements Using Scanning Probe Microscopy

Prof. Rosenwaks is heading a research group of 10 graduate students and scientists concentrating on: nanoscale electrical measurements, Kelvin probe force microscopy (KPFM), nanodomain engineering in ferroelectrics, and local measurement of surface density of states in organic and inorganic semiconductors. The laboratory includes 5 KPFM systems operating in air, controlled humidity, and ultra-high vacuum environments.

Current Research Projects:
- Nanoscale Potential Distribution in Organic Materials and Devices.
- Nanoscale characterization of semiconductor surface states.
- Nanostructured Ferroelectrics: a new technology for optical devices.
- High Voltage AFM for various applications.
- AFM tip– Semiconductor electrostatic interaction.

References:

Micrometer size organic thin film (10 nm thick) field effect transistor (OFET) measured by KPFM to extract the electronic density of states, charge carrier mobility, and Einstein relation in molecular amorphous materials.
Activities related to atomic force microscopy and nano scale characterization

The activity in the laboratory is divided into macroscopic, microscopic and nano-scale electrical characterization, as well as simulation of solid state devices and radiation detectors in particular. The emphasis of the research is on radiation-induced defects as well as on as-grown defects. The radiation-induced defects are divided into point defects and defect clusters. Many of the defects and defect complexes are unstable near room temperature, and thus evolve with time changing the material properties. We attempt to observe the electrical activity of defect clusters by atomic force microscopy. Another aspect of the research is to study the electrical activity of chemically etched surface of CdZnTe semi-insulating crystals. We were able to observe large scale linear faults on the surface penetrating deep into the bulk, as shown in Fig. 1.

We are also involved in studies of thin films (<100 nm) for future microelectronic applications, etc. A relatively new activity starting these days involves study of trapped charge in sub-micron ONO (Oxide/Nitride/Oxide) memory devices. We are also involved in sub-micron device simulations, using commercial TCAD software.

References:

Fig. 1: Extended faults on the surface of etched CdZnTe. (a) Topography image with 5 nm height variations. (b) Surface potential difference image with 100 mV dynamic range

Tel: 972-3-640 5214
Personal Page: http://www.eng.tau.ac.il/~aruzin/
Regardless of the specific application, the key requirements from any optical system are compactness and low loss. Nano-scale optical components enable the realization of dense, highly functional integrated optical circuits while low-loss improves the efficiency and performances of the system. Our research is focused on achieving these characteristics by developing novel wave guiding concepts and optical materials. Currently we are working in two main directions. The first direction is achieving tight confinement of light using distributed feedback. The objective is to develop components such as waveguides, resonators etc. that are capable of confining light in sub-micron dimensions. The applications are ultra-dense photonic processors for telecom and sensing applications. The second project deals with the development of new optical polymeric materials and soft-lithography molding methods capable of fabricating nanometer-scale features. Our results so far include the demonstration of the world smallest semiconductor laser, an ultra-sensitive biochemical sensor and a novel tunable reflector based on electro-optic polymer micro-cavities. In the future we intend to expand our activity to 3D polymeric nano-photonic components and integration of sensor-arrays with micro-fluidic channels.

References:
Nano-chemistry for electronics applications – Physical and electrical characterization of electronic devices for CMOS technologies made by various chemical techniques such as self assembled monolayers and surface catalyzed auto catalytic electrochemical processes. The research involves studying of the basic chemistry and electrochemistry of those structures as well as the fabrication steps and the integration onto CMOS compatible structures that can be used for electronics and nano-bio interfacing applications.

Interconnects applications for ULSI – nano-scale Cu Damascene interconnect structures, Cu deposition on nano structures with high aspect ratio, barrier and capping layers, deposition on low-k (low dielectric constant) insulating materials. Electroless plating of Cu wires, Co and Nickel alloy barriers on low-dielectric constant materials. The group main research activities are on the following topics: Electrical properties of interconnect structures, materials properties – composition, texture, morphology, field effect transistors applications, electrical characterization, physical modeling, electrical modeling. The main applications that are being investigated today:

1. Cell on chip applications – integration of cells on bio-chips for functional sensing of molecular components in aqueous solutions. The cells are genetically engineered to generate a readily detectable electrical signal upon sensing toxicants; this signal will be detected by either nano-electrodes or the ion-sensitive field effect transistors, amplified, interpreted and broadcast by the electronic circuitry. Both nano-electrodes and the transistors will be made using self assembled techniques.

2. Directed metallization of cells for integrated electrochemical nano-biochip – electroless deposition in two levels: molecular level and cellular level and studying the impact of metal deposition of cells on integrated biochip. It will be followed by experimental section which includes enzyme/cell metallization and activity experiments, evaluation of the immobilization of the metallized cells and electrochemical measurement of the metallized cells.

References:


Millions of people throughout the world become blind as a result of devastating disease or trauma. In the Western world, the main factors leading to blindness are diseases such as diabetes, age related macular degeneration (AMD) and glaucoma, or traumas such as car and work accidents, terrorism and wars. In the third world, malnutrition as well as infective and toxic alimentation are the leading factors of blindness. Our work is based on our hypothesis that retinal ganglion cells (RGC) are capable of growing their axons following injury; however, the non-permissive environment prevents them from doing so. We further hypothesize that removal of the non-permissive cues and supplement the RGCs with axonal growth promoting substances will lead to axonal functional regeneration. Based on these hypotheses we intend to use holistic approach that combines nanotechnological methodologies that will supplement the neurons with the necessary cues that will accelerate their growth. Our specific aims are: (i) Implantation of biodegradable three-dimensional scaffold in the optic nerve and assessing its ability to promote RGC survival and axonal regeneration. (ii) Spatial and temporal controlled secretion from specially designed nano-structures that will implanted in the optic nerve. (iii) Implantation of nanochips and electrodes in the optic nerve in order to generate biofeedback necessary to maintain homeostatic conditions.

References:
Bacteriophages (phages) have been used for over a century for (un-orthodox) therapy of bacterial infections, for nearly half a century as tools in genetic research, for nearly two decades as tools for discovery of specific target-binding proteins (mainly antibodies and peptides, known as “phage display”), for nearly a decade as tools for vaccination or as gene delivery vehicles and very recently as tools for assembly of electronic materials by nanofabrication.

Filamentous phages (*Inovirus*) comprise a family of bacterial viruses that have only about 10 genes and grow in well-characterized hosts, the Gram-negative bacteria. Structurally, the filamentous phage is a particle of nanometer dimensions comprising a sheath of several thousand identical alpha-helical coat proteins in a helical array that during phage maturation, self-assemble around a single-stranded circular DNA molecule at the core. A few minor proteins cap the particle at each end.

We present a novel technology related to the field of targeted drug delivery in the form of targeted drug-carrying phage nanoparticles. Our approach is based on genetically-modified and chemically manipulated phages. The genetic manipulation endows the phages with the ability to display a host-specificity-conferring ligand (target-specific peptide, recombinant antibody or other target-specifying entity) on their surface. The bacteriophages are chemically conjugated through labile linkages that are subject to controlled cleavage to a therapeutic. In the conjugated state the drug is kept in an inactive prodrug state and is released and concomitantly re-activated at the target. As such, the drug-carrying phage nanoparticles may be useful as targeted drug delivery vessels for the treatment of various pathological conditions. The targeted drug carrying phage nanoparticles have a large drug-carrying capacity in excess of $10^4$ drug molecules/target site. Currently we are evaluating this approach toward the elimination of pathogenic bacteria and for cancer therapy.

**References:**
We have no publications, yet, that resulted from our Nano activity. We do have a patent application:
Photovoltaic devices are fabricated by assembling the highly efficient photosynthetic reaction center protein in solid state scaffolds. The assembly of the soft protein-made photosystem I (PS I) into a solid state scaffold without damaging the activity is very challenging therefore the robust chlorophyll-protein PS I reaction center from cyanobacteria was selected. Induction of cysteine mutants in the outer loops of this membrane protein enabled fabrication of oriented self assembled monolayer by formation of sulfide bonds to metal electrodes as determined by AFM. In the biological membranes the efficient PS I generates light-induced vectorial charge transfer across nano size protein creating a potential of 1 V in 200 ns at quantum efficiency of 1 and energy conversion efficiency of 58%. It was found that the self assembled dry PS I retained its activity as it generated a reversible photovoltage of 1 V as measured by KPFM. A photocurrent of 0.35 A/cm² was measured when the oriented self assembled monolayer of PS I on metal electrode was capsulated in a nitride micro cell and topped with the transparent indium tin oxide electrode. These photovoltaic devices are being used for development of cost effective solar cells. It can be applied in the development of bio-nano-photo-sensors, in artificial vision and as photo-switches in molecular electronics.

References:
Biotemplating of synthetic gels and metals by stabilized protein crystals for the fabrication of novel composite materials: [1, 2]. The project involves design, preparation and characterization of protein crystals used as biotemplates [3] and studies on factors affecting the voids array formed within protein crystals. This project involved 4 PhD programs: two submitted and approved and two ongoing. These projects are carried out in collaboration with Prof. Frolow from our department and served as basis for its extension to collaboration with Prof. Gurevitch from Plant Sciences.

Directed metallization of biologically active proteins and cells for the fabrication of nanosized biosensors and biochips: [ref 4 & two patent applications]. The feasibility of new methods for the fabrication of active protein-metal hybrids was demonstrated. Adaptation of these methods for the metallization of microbial cells is ongoing. This project is carried out in collaboration with Prof. Shacham from Physical Electronics and Prof. Rishpon from our department.

References:
The self-assembly of well-ordered amyloid fibrils is the hallmark of several diseases of unrelated origin, including Alzheimer’s disease, Type II diabetes, and Parkinson’s disease. We suggested, based on experimental and bioinformatical analysis, that aromatic stacking interactions may provide energetic contribution as well as order and directionality in the self-assembly process. Our model recently gained experimental and theoretical support from leading groups and it serves as the basis for the development of novel therapeutic agents to treat the disorders. In the path of our reductionist approach toward the identification of the shortest motifs that mediate the assembly of the fibrils, we demonstrated that the diphenylalanine core-recognition motif of the Alzheimer’s β-amyloid contains all the molecular information needed for efficient assembly into well-ordered, stiff, and elongated nanotubes with a remarkable persistence length, that could serve as a mold for the fabrication of nanoscale inorganic material. We later reveal that diphenylglycine, a highly similar analogue and the simplest aromatic dipeptide, forms spherical nanometric assemblies. These properties of the peptide nanostructures, taken together with their biological compatibility and remarkable mechanical, and chemical stability, may provide very important tools for future nanotechnology applications. We recently demonstrated the ability of the nanotubes to serve in advanced electrochemical sensing.

References:
We study the dynamics of the interactions of proteins with cholesterol-enriched nanoscale lipid domains (lipid rafts) in the membranes of live cells. Such domains are believed to play important roles in cellular signaling. Although extensively characterized in artificial membranes and in detergent-resistant membrane fractions, their existence in live cells is under debate. We developed biophysical methods based on fluorescence recovery after photobleaching (FRAP) to study rafts in live cells. By changing the area illuminated by a submicron laser beam, in combination with cholesterol depletion treatments, we can differentiate between lateral diffusion and membrane-cytoplasm exchange, and investigate the role of nanoscale rafts in controlling the membrane interactions and signaling of Ras proteins. These proteins regulate cell growth, and constitutively active Ras mutations contribute to the development of many human tumors. These studies can pave the way to understand the regulation of different Ras signaling pathways and to find ways to disrupt Ras signaling.

References:
DNA is a fascinating soft material that naturally expresses two of the three main features required from molecular nanoelectronic components, namely recognition and specific structuring (sequence, length). The third additional property that is needed in order to implement DNA-derivatives for electrical device applications is conductivity. The central objective of this multidisciplinary project is, thus development of DNA-based conductive nanowires for nanoelectronics. There are two main goals of this the project. The first is to produce double-stranded [1,2], triple–stranded [3] and G4-DNA [4] molecular nanowires as well as complexes of the above wires with various redox active ions and to characterize their electrical properties. We recently succeeded to produce for the first time a novel 4g-DNA nanowires that show encouraging conductivity signals while preserving the structuring and recognition qualities. The second goal of the project is development of model nanoelectronic devices on the basis of the above DNA-Based wires. Our strategy is to use specific alterations of the sequence and inclusions of hybrid inorganic elements to pre-planned locations in the conducting wire. A device resulting from this approach will be nanometric in size and embedded in the conducting wire itself. Finally, we hope to establish first prototype single-DNA-based electronic devices. Several experimental and theoretical groups working in Israel and Europe are working as a team towards the realization of the goals of this interdisciplinary project.

References:

Our efforts in the drug delivery arena focus on two drug delivery technologies that are inventions of our group. Both are based on biomaterials, and can form vesicular nano-sized particles. The particles of one technology are named Bioadhesive Liposomes (BALs), consisting of regular liposomes - hence their shell is a lipid bilayer membrane. Surface-modification by covalent binding of target-recognition agents such as hyaluronan, collagen, EGF or gelatin to the liposomal surface, renders them bioadhesive. The particles of the second technology are named gagomers (GAGs), their shell is made of hyaluronan, and their interior contains water and lipids. The goal is to apply such nano particles as drug carriers for the treatment of pathologies such as tumors, infectious diseases and inflammations, that require systemic administration, in order to improve deficiencies of treatment with free drugs, as the latter lead to poor therapeutic responses and to treatment failures. Our conceptual approach, for any project, is to start at the molecular level and proceed systematically to studies in cell cultures, and then to animal studies. At the molecular level we investigate structural, physicochemical and biochemical properties of these nanoparticles. In cell cultures we explore cell–carrier interactions with particular emphasis on: kinetics and thermodynamics of cell–carrier binding, cellular localizations of carrier and drug, the mechanisms by which carrier-mediation affects drug entry into cells, and therapeutic activity. The in vivo studies focus on pharmacokinetics, drug and carrier biodistributions, adverse effects, and therapeutic responses.

References:

Drug delivery by nano-particles based on biomaterials: biophysical properties, cell-particle interactions and therapeutic responses

Tel: (972)-3-6409822
Fax: (972)-3-6406834
Email: rimona@post.tau.ac.il
Dr. Dan Peer  Life Sciences

Selective targeting and reprogramming of leukocytes using fully degradable nanomedicines

Our lab is studying how to manipulate cells' functions in order to generate novel therapeutic strategies to treat inflammatory diseases and cancers. We are combining a multidisciplinary approach including immunology, cell and molecular biology, genetics, protein engineering, material sciences, nanotechnology and computational techniques to develop innovative therapeutics to target specific cells within the immune system. In addition, we are developing nanomedicines by designing highly selective targeting moieties and novel nanocarriers, with an ultimate goal to translate some of our findings into clinical settings.

We are particularly interested in
1. Identifying key genes responsible for pluripotent hematopoietic stem cells self-renewal properties.
2. Studying the role of cell cycle regulators in proliferation, migration, and cytokine production in lymphocytes, macrophages and dendritic cells during inflammatory bowel diseases and rheumatoid arthritis.
3. Developing and studying novel approaches to target cancer stem cells.
4. Harnessing siRNAs and miRNAs as novel tools for drug discovery and for therapeutic applications.

References:

Selective targeting of siRNAs (red) into activated lymphocytes (green) using fusion protein that target conformation-selective integrin LFA-1. Naïve cells (not stained) do not uptake siRNAs.

Tel:  (972)-3-6407925
Fax:  (972)-3-6407925
Email: peer@post.tau.ac.il
Personal Website: http://www.tau.ac.il/lifesci/departments/cell_r/members/peer/peer.html
Carbon nanotubes on amperometric electrodes
We have effectively exploited the unique electronic properties of carbon nanotubes (CNT) in electrochemistry as a means of promoting the electron transfer reaction for the development of enzyme based sensors. CNT were attached to gold or carbon electrodes and applied in a sensitive detection of hydrogen peroxide employing the enzyme horse reddish peroxidase immobilized on a CNT modified electrode. This sensor was capable to measure enzymatic activity released from the *mycobacteria smegmatis* (a model system for *mycobacteria tuberculosis*). CNT attached to electrodes were also exploited in a highly sensitive electrochemical enzyme immunosensors.

Peptide nanotubes on amperometric electrodes
In addition, we have examined the possibility of employing peptide nanotubes (PNT) as catalytic elements in amperometric biosensors [1]. Voltammetric and time based amperometric techniques were applied to demonstrate the significantly improvement electrochemical parameters by the PNT. These findings clearly show that this novel class of peptide nanotubes provides an attractive component for future electroanalytical biosensors.

Lipid nanolayer on gold electrode
We have investigated interactions between receptors and hormone by following the impedance changes in 5-7nm thick lipid bilayers on gold electrodes. The system respond to estrogen or testosterone at physiological concentrations. Moreover, it enables the detection of xenoestrogens like xenoestrogens that are a health risk in the environment [2].

Lab on a Chip
We developed an innovative electrochemical 'lab on a chip' system that integrates the applicability of physiological reactions to serve as biosensors with the advantages of micro electro mechanical systems (MEMS). The novel specific design and process of the nano-biochip adjusted to an exclusive biochemical process enables highly accurate, sensitive and rapid diagnosis of physiological reactions by a hand held miniaturize device [3]. This system was used in the detection the response of microorganisms to acute toxicity in water.

References:
Prof. Zeev Schuss  Mathematics

Ionic permeation in protein channels of biological membranes and applications to models of neurons and cardiac myocytes

My activity concerns construction of mathematical models of ionic permeation, selectivity, and gating in protein channels of biological membranes and their analysis. I integrate the channel and gating models in models of neurons and cardiac myocytes to analyze and predict their function under given physical, chemical, and biological conditions. My models, which have been borne out by experiment, include the increased conductivity of potassium channels under the influence of low frequency (cca 16 Hz) low intensity magnetic fields (pico to micro Tesla), the lowering of cytosolic calcium in cardiac myocytes, and the shortening of the QT interval in rat and Guinea pig EKG. More theoretical work includes a theory of Brownian and Langevin simulations of permeation, formulation of evolution equations for the non-equilibrium density of interacting ions, and other related problems in statistical physics. The theoretical work is based on asymptotic methods that I developed for the analysis of stochastic differential equations. I have two Ph.D. students in applied mathematics, one in electrical engineering in TAU working on this project. I cooperate with researchers in the departments of biomedical engineering and physiology in TAU and also with applied mathematicians and neuro-physiologists in the WIS (Brain Research Center).

References:
nanomedicine is medical treatment at the level of single molecules or molecular assemblies that provide structure, control, signaling, homeostasis, and motility in cells, i.e., at the “nano” scale of about 100 nm or less. There have been many scientific and technological advances in both physical and biological sciences over the past several years that make nanomedicine research particularly attractive at this time. New tools are being developed that permit imaging of structure at this scale, high-speed measurement of the dynamic behavior of these molecular assemblies, and the forces produced by molecular machines as well as the forces needed to disrupt them. These advances are complemented, on the biological side, by the dramatically expanded knowledge of the human genome, a greater understanding of the pathophysiology of specific diseases at the molecular scale, the need to develop more specific treatments of disease, and the desire to understand the dynamic behavior of dysfunctional cellular machinery in the context of the total cell machinery. The need for more precise measurements of the behavior of the nanomachinery within cells combined with the expanding array of tools capable of making these measurements led to the identification of Nanomedicine theme of “New Pathways to Discovery”.

Stem cell has a broad use in cell therapy and tissue engineering. Mesenchymal stem cells derived from the bone marrow are able to differentiate to various lineages: osteogenic, chondrogenic and muscle cells or behaves more plastic and differentiates to other tissues. Before stem cells can be used for cell therapy, the definition of their identity and culturing conditions needs to be explored. The research conducted at the laboratory is to answer the question of mesenchymal stem cells (MSC) identity. We are using animal models of to retrieve mesenchymal tissues and to culture MSCs to analyze their gene profiling. Micro array used to explore the gene expression and analysis of growth factor, hormone, and genes of signaling pathway involved in cell activation and differentiation according to tissue source and profiling. This knowledge will enable to develop molecular and biochemical platform that enables the isolation and manipulation of the stem and progenitor cells to differentiation. The regulatory circuit will be applied and will enable the knowledge to set up the conditions for cells expansion and maintaining their phenotype and control the stem cells differentiation to utilize the cells as biomedical devices. This approach will lead to explore the encoded information relevant to cells differentiation in specific contacts that will enable to produce well-defined populations of programmed cells. It will lead to numerous applications in the fields of molecular medicine and cellular Nano-biotechnology that can apply to a new approach to bioengineering.

References:
The activity of research group in the field of nanoscience and nanotechnology addresses two main topics: (1) Electrical enhancement of delivery of nanoparticles carrying drugs into cells (electroendocytosis) and toxicology of nanoparticles; (2) Nanoscale dynamics of the cell surface of cells. In order to achieve more effective therapies while eliminating the potential for both under- and overdosing, we have developed a novel methodological platform to induce highly efficient transfer of specifically designed nanoparticles carrying drugs into cells. The method is based on exposure of cells to trains of low unipolar electric fields which leads to an efficient uptake of macromolecules and nanoparticles into cells. One application of this methodology is the treatment and cure of solid tumors in mice bearing different types of metastatic cancer.

The study of nano-scale local dynamics of the cell surface addresses two major directions (i) Understanding the relationship between the molecular structure of the membrane-skeleton complex and nano-scale cell membrane fluctuations under physiological and pathological situations; (ii) The non-linear analysis of time series of cell membrane fluctuations and their use as specific “signature” patterns for diagnosis employing a “cell on chip” configuration. This study involved the development of novel methodologies to monitor nano-scale cell membrane fluctuations.

References:
Tumors consist of three general compartments: tumor cells, tumor vasculature and non-endothelial tumor stroma. The ability of cancers to grow is dependent on the formation and maintenance of new blood vessels from pre-existing vasculature in a complex process referred to as Angiogenesis (Figure 1). Tumors may remain small and dormant if unable to elicit functional angiogenesis. Consequently, the microvascular endothelial cell, recruited by a tumor, has become a paramount factor in tumor progression and metastases formation making both the tumor cells and their surrounding stroma a target for combined anticancer and anti-angiogenic therapy.

Selective therapy remains a key issue for successful treatment in cancer therapy. Prolonged administration of effective concentrations of chemotherapeutic or anti-angiogenic agents is usually not possible because of dose-limiting systemic toxicities involving non-malignant tissues. Therefore, a constant effort has been the development of new drug delivery systems that mediate drug release selectively at the tumor site. Multimodality targeted nanomedicines offer the potential for improved efficacy and diminished toxicity. One way to achieve such selectivity is to activate a prodrug specifically by a confined enzymatic activity. In this concept, the enzyme is either expressed by the tumor cells or the tumor endothelial cells, or is brought to the tumor by a targeting moiety. The prodrug is converted to an active drug by the local or localized enzyme at the tumor site. Alternatively, the lower pH in the tumor microenvironment can be utilized for selectively activating a prodrug.

Our strategy for advancing the field of vascular biology and the development of vascular targeting nanomedicines is by:

1. **Characterization of tumor vasculature for tailored-made therapy.** Identifying new molecular markers on tumor endothelial cells in order to develop better drugs and better targeting moieties.
2. **Design of novel nanocarriers as strategies to target angiogenesis inhibitors to tumor vasculature.** To improve the therapeutic index of chemotherapeutic and antiangiogenic agents by conjugation to polymeric nanocarriers.
3. **Investigation of the mechanism of action of angiogenesis inhibitors** (endogenous and pharmacological inhibitors).
4. **Intravital non-invasive molecular imaging** of treated tumor-bearing mice to follow tumor progression, pharmacodynamics and pharmacokinetics of the synthesized nanomedicines.

Our lab has recently designed some novel anti-angiogenic and antitumor polymer-drug nano-
conjugates (Figure 2). Our results point at our polymer therapeutics as novel bi-specific nano-conjugates targeting both the tumor epithelial and endothelial compartments warranting their use on a wide spectrum of primary tumors and metastatic ones.

Figure 2. Intravenous administration of a FITC-labelled polymer-drug nano-conjugate with a diameter size of 100 nm into: (a) Normal vasculature adjacent to (b) tumor blood vessels in a subcutaneous implanted osteosarcoma. Tumor vessels demonstrate exaggerated size, tortuosity, and permeability. (c) Internalization of a FITC-labelled (green) nano-conjugate (d) into a human umbilical vein endothelial cell (HUVEC).

References:
**Dr. Ella Sklan**  Medicine

**Interactions of positive strand RNA viruses with the host cell**

Hepatitis C virus (HCV) is an important cause of worldwide liver disease. Current therapies are inadequate for most patients. Improving the understanding of the life cycle of this virus may provide opportunities for new antiviral strategies. HCV is a small, positive single-stranded RNA virus; the viral particles have a uniform diameter of 50nm and contain a 9.6kb genome encoding a single ~3000 amino acid polyprotein. This polyprotein is proteolytically processed into structural proteins that compose the mature virus and non-structural (NS) proteins that are involved in replicating the viral genome. We are interested in identifying and characterizing interactions of these viral proteins with the host cell, using yeast screens and proteomic approaches as our major tools. In addition to identifying new viral-host interactions we aim to develop high-throughput screens (using Quantum dots based Bioluminescence Resonance Energy Transfer (BRET) and Fluorescence Resonance Energy Transfer (FRET)) for small molecule inhibitors of our previously identified and confirmed interactions such as the interaction between Hepatitis C non-structural protein (NS5A) and a host protein (TBC1d20) [1, 2] that was found to be essential for hepatitis C replication (see figure). The small molecules identified in this powerful cell based assay could serve as novel antiviral compounds.

**References:**


Depletion of TBC1D20 inhibits HCV RNA replication. Wn is a colony formation assay using HCV subgenomic replicons. These replicons are fully competent for viral-RNA genome replication but lack the viral structural proteins and instead carry a neomycin selection gene. Co-transfection of these replicons into Huh7 hepatoma cells together with siRNAs depleting TBC1D20 showed that HCV replication is dramatically inhibited.
It is widely believed that memory is grounded in synaptic connections. However, the principles regulating encoding, storage and retrieval of information in synaptic networks remain elusive. Our research is focused on the endogenous mechanisms controlling memory capacity in adult brain. Our main target is to determine how the quality and quantity of ongoing neuronal activity affect the properties of individual pre- and post-synaptic compartments, neural connection (few synapses), synaptic network (thousands of synapses), and the whole system. To fulfill this goal, we are applying combination of electrophysiology, functional quantitative imaging, molecular biology, and behavioral techniques. Our recent results indicate that uncorrelated pattern of neuronal activity plays a key role in synaptic network organization and memory function.

References:
Growth factors and their receptors that play important roles in normal development have often been implicated in tumorigenicity and metastasis. In the past years, attention has focused on the role of the tyrosine kinase growth factor receptor Met and its ligand, hepatocyte growth factor/scatter factor (HGF/SF), in metastasis. HGF/SF is a paracrine factor produced primarily by mesenchymal cells that induces mitogenic, motogenic, and morphogenic effects on a wide variety of cells. Met-HGF/SF signaling can increase production of proteases and urokinase, which are important for metastasis and induce angiogenic activity. HGF/SF transgenic mice develop a broad array of histologically distinct tumors. Mutations in the Met tyrosine kinase domain have been identified in both hereditary and sporadic forms of human papillary renal carcinoma. Furthermore, Met and HGF/SF have been implicated in breast cancer.

We are developing Met-HGF/SF nanoparticles based direct molecular imaging modalities for in vivo imaging of tumors, lymph nodes, and distal metastasis. Fluorescent gold- and gadolinium-based nanoparticles are coupled to antibodies against Met or coupled to HGF/SF. The labeled proteins retained their biological activities. Cellular molecular imaging techniques are used to study the interaction between the Ab/ligand to the receptor. We are also developing high-resolution functional molecular optical and MRI techniques to image Met and HGF/SF overexpression in tumors and metastasis. HGF/SF induce dramatic increase of blood flow in the tumor. Using optical imaging modalities and nanoparticles, we imaged HGF/SF increase in blood flow in a single blood vessel. Our recent studies also show that Met functional molecular imaging improves mapping of local and distant metastasis. The primary aim of our work is to develop novel transgenic mice and nanoparticles-based molecular imaging methodologies to visualize and measure the expression and activity of tyrosine kinase growth factor receptor and their ligand in vitro and in vivo. We utilize confocal based intravital molecular and high resolution MRI imaging to visualize the expression of the receptor and its interaction with the ligand in vivo and in vitro.

References:

This work is part of a collaboration between Tel Aviv University, Sheba Medical Center the Van Andel Research Institute (Grand Rapids MI) and Michigan University, Ann Arbor MI.
PROGRESS REPORTS
Prof. Ari Barzilai

Introduction
Millions of people throughout the world become blind as a result of devastating disease or trauma. In the Western world, the main factors leading to blindness are diseases such as diabetes, age related macular degeneration (AMD) and glaucoma, or traumas such as car and work accidents, terrorism and wars. In the third world, malnutrition as well as infective and toxic alimentation are the leading factors of blindness.

Hypothesis
Our work is based on our hypothesis that retinal ganglion cells (RGC) are capable of growing their axons following injury; however, the non-permissive environment prevents them from doing so. We further hypothesize that removal of the non-permissive cures and supplement the RGCs with axonal growth promoting substances will lead to axonal functional regeneration.

Objectives
Based on these hypotheses we intend to use an integrative approach that combines nanotechnological methodologies that will supplement the neurons with the necessary cues that will accelerate their growth. Our specific aims are:

1. Implantation of biodegradable three-dimensional scaffold in the optic nerve and assessing its ability to promote RGC survival and axonal regeneration.
2. Spatial and temporal controlled secretion from specially designed nano-structures that will implanted in the optic nerve.
3. Implantation of nano-chips and electrodes in the optic nerve in order to generate biofeedback necessary to maintain homeostatic conditions.

Results

Unique model of axotomy:
This model of axotomy is unique in its design. The complete cut of the axons is done by using special designed tools made from micro glass pipettes and used to generate a complete cut of the optic nerve axons without affecting the vascular supply to either the retina or the nerve and leaves the neural scaffold intact. It is now fully operational and all the experiments are conducted using this model system.

To measure the extent of the axonal growth process, we have adopted a unique method of MRI that enables us to visualize the growth process in vivo. The rats were injected intravitreally with Mn^{2+} 24 hours prior to MRI analysis. In addition, we dissected out the optic nerves and assess the growth process using specific markers of neuronal growth. The axotomized optic nerves were injected with 3 types of self-assembling peptides and bio-gels made out of hyaluronic acid and laminin (HA). The results are very encouraging.
We have analyzed the results of one self-assembling peptide AM-1-3 (received from Prof. Mitraki, WP-1) and the HA. In both cases the biogel scaffolds enhanced the growth process as assessed by the MRI analyses, and confocal microscopy (cholera toxin and the GAP-43). The biogels provided a substrate that enabled the growing axons to cross the lesion site and to grow their axons beyond that point. No such phenomenon was observed in axotomized non-treated optic nerves. Surprisingly, the MRI analysis has shown that injured axons concomitantly injected with HA have reached the area of the optic chiasm 28 days post injury. In addition to the injection of biogel scaffolds we have found that injection of activated mononuclear cells into the injured optic nerve prevented the Wallerian degeneration of the axotomized optic nerve.

Figure 2. MRI of the Mn$^{2+}$-enhanced visual pathway obtained from a control group rat 24 hours after injection of 150 nmol Mn$^{2+}$ into the right corpus vitreous. The optic nerve is labelled with yellow arrows. While in control untreated rats the Mn$^{2+}$ induces signal enhancement, no traces of signal enhancement are observed in axotomized animals. Marked degree of axonal regeneration is detected in axotomized optic nerve treated with gels made out of hyaluronic acid (HA). The Mn$^{2+}$ label reached the optic chiasm but not the superior colliculus. The MRI was performed one month after injury.
The key nano activity our group was engaged in is the ongoing project of evaluating targeted drug-carrying bacteriophages and potential nanomedicines. Bacteriophages (phages) have been used previously for therapy of bacterial infections, for genetic research, for discovery of specific target-binding proteins, as tools for vaccination or as potential gene delivery vehicles. In the ongoing project we are evaluating the possibility of applying filamentous bacteriophages as targeted drug carriers for two modalities: 1) the eradication of pathogenic bacteria as a means to meet the challenge of spreading antibiotic resistance among pathogenic bacteria. 2) Application of the phages as anti tumor agents. Having provided proof-of principle of the potential of both the anti-bacterial and the anti-cancer phages in cell culture systems (published 2006 and 2007), we have now progressed to next level towards preclinical development: testing our platform in animal models. These targeted drug-carrying phages, due to genetic and chemical modifications represent a modular targeted drug-carrying platform of nanometric dimensions where targeting moieties and conjugated drugs may be exchanged at will.

Specifically, the study is based on our ability to genetically engineer and chemically modify filamentous phages that display or form a stable complex with a target-specific antibody on their coat and are used to deliver cytotoxic drugs to target cells. The antibodies are specific for binding pathogenic bacteria, or an anti-tumor-associated-antigen antibody. The genetic modification endows the phages with binding specificity towards the target cells and also modifies the drug carrying capacity as well as the pharmacokinetic properties of the phages. The drugs are linked to the phages by means of chemical conjugation through labile linkers subject to controlled release at or inside the target cell. We have demonstrated the feasibility of using this platform against pathogenic bacteria. In a related study we demonstrated growth inhibition of tumor cells by hygromycin and by doxorubicin-conjugated phages targeted via chimeric anti ErbB2 and EGFR antibodies. We also found that targeted drug-carrying phages are not toxic to mice (up to $10^{11}$ phages IV or IP). We further found that phages that carry chloramphenicol connected through an aminoglycoside linker are greatly reduced in immunogenicity, and have a prolonged circulation time. In yet unpublished experiments we could apply targeted chloramphenicol-carrying phages in a lethal infection model of Staphylococcus aureus bacteria in BALB/c mice. We found that we can protect the mice from a lethal bacterial challenge.

References:
**Introduction**

The Electrical Discharge and Plasma Laboratory at Tel Aviv University in an inter-faculty facility in which the science of electrical discharges and the plasma which they produce are investigated, and applications of these phenomena are developed. Much of the applications are in the realm of plasma processing of materials, and include deposition of nano-structured thin films and coatings, nano-texturing of tribological surfaces, and production of nano-particles.

**Vacuum Arc Deposition of Nano-structured Thin Films and Coatings**

Vacuum arc deposition exploits the high velocity fully ionized metal vapor plasma jet produced by high current electrical discharges in a vacuum environment to produce thin films and coatings. The laboratory designed and built a unique triple-cathode vacuum arc plasma source. The cathodes can be operated simultaneously to produce multi-component "designer alloy" films, or alternatively to produce multi-layer films. In a completed project, nano-layered films of TiN, NbN, and ZrN, and well as multi-component films comprised of these components were rapidly deposited (at ~1 µm/min) and characterized. "Superhard" TiN/Nb films were produced. The lab participated in a European Union sponsored coordination action entitled “Deposition of super-hard nanocomposite films by plasma processing”, and in this framework hosted the International Conference on Super-hard coatings. Currently the lab is studying jointly with Ulsan University hard coatings based on nano-layered and nano-composite Al2O3/ZrO2, sponsored by the ministries of science of Israel and Korea, and the deposition of ceramic/fullerene composite films jointly with the Technion.

**Nano-structuring of Tribological Surfaces**

The lab is investigating nano-structuring of wear surfaces using a pulsed arc in air. In this method, the texturing is preformed in open air on samples at room temperature, in cooperation with the Holon Institute of Technology. Discharges are produced between a steel sample and a high voltage counter-electrode. The counter-electrode was 3 mm diam steel rod with a 28° cone tip. Each discharge produces a small nano-textured dimple on the sample surface, which serves as a micro-reservoir for lubricant, which may be a conventional material such as the solid lubricant Stearin, or nano-fullerenes of MoS₂ suspended in mineral oil. The micro-hardness of treated steel surface increased by factor of 10-40%, due to formation of fine grain structure and ferrite-austenite transformation. Lifetime of the lubricant film increased more than order of magnitude.

**Nano-particle Production and Characterization**

Pulse submerged arcs are high current electrical discharges sustained between electrodes submerged in a liquid. The discharge produces a plasma bubble within the liquid, characterized by extreme temperature gradients. These discharges are investigated in the lab for producing nano-particles based on the electrode materials, and/or the liquid in which they are submerged. Pulsed arc production of WC powders in deionized water and analytical ethanol was studied. The arc was ignited between a 99.99% graphite (C) and a 99.5% W electrode. The pulse energy and duration were in the ranges of 7.7-192 mJ and 25-65 ms, respectively. The highest quantity of WC₁ₓ was produced by arcing a C anode with W cathode in both liquids and for different discharge energy and capacitors. Arcing in ethanol increased the production of the WC₁ₓ phase. The number ~10 nm particles was by two orders greater when using a W anode and a C cathode pair than by using the opposite polarity while arcing in ethanol. Arcing with a W anode and C cathode in water produced bigger particles, uniformly distributed in the range of 0.5-2.5 µm.
An important consequence of electron-vibration interaction in molecular-junction-transport is heat generation, i.e., energy transfer to the underlying nuclear motions. In balance with heat dissipation, this has important implications on the issue of junction stability. Advancement in molecular electronics necessitates thorough understanding of these processes in molecular junctions. Such an understanding depends on the ability to monitor non-equilibrium occupancy of vibrational levels at current carrying junctions as a function of bias. We report (in cooperation with the group of Y. Selzer) on the realization of such a capability by utilizing the Stokes (S) and AntiStokes (AS) components of Surface Enhanced Raman Spectroscopy (SERS) to probe the effective temperature of current carrying junctions. In our specific junction, all Raman active modes show similar heating as a function of bias at room temperature, suggesting fast internal vibrational relaxation processes. These results demonstrate the power of direct spectroscopic probing of heating and cooling processes in nanostructures.

Reference:
Superconductivity and magnetism at interfaces between insulating perovskites

It has been recently discovered that the interface between the two non-magnetic insulators: LaAlO₃ and SrTiO₃ is highly conducting and has the properties of a two dimensional electron gas (2DEG). It has also been demonstrated that in some samples this interface exhibits superconductivity with transition temperature $T_c \approx 200\text{mK}$, and in others ferromagnetism. The main parameter responsible for the various phases seems to be the number of charge carriers. In our laboratory we are trying to navigate through the phase diagram of this interface by varying the number of charge carriers using gate voltage and via proximity to other superconductors.

Tuning Superconductivity in Perovskites Using Organic monolayers

In a material undergoing a superconducting transition, the electrons condense into a macroscopic ground state below a critical temperature $T_c$. We use organic molecular and bio-inspired thin films in order to control the properties of high $T_c$ cuprate superconductors and other perovskite superconductors. This will be done by chemical and opto-electrical tuning of the electronic properties of the superconductor surface using bio-optical active proteins and polar self assembled monolayers.

Superconductivity and Magnetism on the nanoscale

Superconductivity is a macroscopic quantum phenomenon. Long range order is established over a coherence length-scale, $\xi$. However, when the superconducting specimen is constituted of weakly connected nano-grains whose size is smaller than $\xi$, or when the coherence length becomes of the size of the crystal unit cell many interesting physical phenomena occur. The first case is realized in granular superconductors (GSC), and High $T_c$ cuprate superconductors (HTCS) fit to the second.

We study the magneto-transport properties and in particular the vortex Nernst effect in granular superconductors Al-Ge and Al-Al₂O₃ where phase fluctuations can be tuned using the grain size and inter-grain resistance as control parameters and in the electron-doped HTCS $\text{Pr}_{2-x}\text{Ce}_x\text{CuO}_{4-\delta}$ (PCCO) near a possible superconductor to insulator and antiferromagnetic to paramagnetic quantum phase transitions.
Nano-scale planar superconductor/ferromagnetic contact

We have produced nano-scale In (S)/Ni(F) contacts in a planar geometry by producing cross junctions, first depositing a thin Ni layer, letting it oxidize briefly, and then depositing an In layer. The junction size range studied was from a few microns down to about 100 nm. It was found that for certain oxidation conditions and junction sizes, the conductance of the junction was dominated by a few pinholes in the Ni oxide layer, effectively making it a point-contact junction. Below the superconducting critical temperature of the In layer the conductance of the junction was found to vary as a function of bias and temperature in a way consistent with the occurrence of electron-hole reflections (Andreev – Saint-James or ASJ reflections) at the interface. This has opened the possibility of fabricating devices where two neighboring such junctions crossed ASJ reflections could take place. In such a device the two members of a Cooper pair could be on separate ferromagnetic legs, which would open several intriguing applications (1).


Nano-scale emerging superconductivity in the High Tc oxides

A new mechanism for high temperature superconductivity has been proposed (1). It is based on properties of the Cu-O-Cu bonds, in which the d-electrons on neighboring Copper atoms are coupled via the p-orbital of the Oxygen. It is in fact this coupling that leads to anti-ferromagnetism in the Copper oxides. But what is envisioned here is that holes introduced in the pristine anti-ferromagnet can under certain conditions gain energy if they get localized on neighboring Cu atoms, if the Cu-O bonds will contract sufficiently. This model predicts the formation of domains consisting of columns of hole rich contracted Cu-O-Cu bonds separated by hole poor columns of stretched Cu-O-Cu bonds. These domains are predicted to form at a temperature that is higher than the transition to superconductivity. This prediction is consistent with the increasing disorder observed in the distance of Cu-O bonds below a temperature of about 150 K in a compound having a maximum critical temperature of 40 K (LaSrCuO), and with the recent observation of domain formation by Scanning Tunneling Microscopy in underdoped cuprates.


Broken symmetry near the pseudo-gap temperature of the High Tc Cuprate YBaCuO in the underdoped phase

Polar Kerr effect measurements performed on YBaCuO single crystals and epitaxial films have revealed the apparition of a magnetic moment below a temperature which is higher than the critical temperature in underdoped samples. The Kerr angle appears below a well defined temperature in a way that suggests a second order phase transition. A very strong field is necessary to reverse the moment obtained when cooling the sample in a weak field, suggesting the existence of magnetic domains.

It remains to be established if the observed transition is related to the formation of domains seen in STM, and if they are consistent with the bond contraction model of Deutscher and de Gennes.

Statistical thermodynamics of fluctuating capsules
Sub-micron membrane vesicles (or liposomes) are commonly used to encapsulate and deliver biochemical agents in various biological and industrial systems. Those semipermeable capsules are osmotically swollen by a fixed number of trapped molecules, while their volume and inner pressure are not prescribed. We have been studying the statistical thermodynamics of this special class of finite-size systems. We have shown that, under rather general conditions, as the number of encapsulated particles is increased, or the outer concentration is decreased, the swelling toward maximum volume exhibits a continuous phase transition. This newly discovered criticality implies a universal behavior of strongly swollen capsules as they approach osmotic lysis. In addition, a unifying scaling analysis has been devised for pressurized and particle-encapsulating random manifolds, encompassing a wide range of systems. We have confirmed the predictions of this analysis in several specific models.

The work has been done by Emir Haleva (PhD student). It is supported by the American Chemical Society Petroleum Research Fund.

Premicellar aggregation of amphiphilic molecules
The formation of nano-sized aggregates (micelles) in dilute solutions of amphiphilic molecules is a ubiquitous and useful phenomenon. Using a new model of micellization, we showed earlier that, under certain realistic conditions, a significant amount of metastable aggregates exist well below the critical micelle concentration – a phenomenon that has been reported also experimentally. (See Activity Report for 2006-2007.) We have extended the theory in two directions pertaining to the experimental and technological relevance of such premicellar aggregates – their lifetime and polydispersity. We have demonstrated that, over most of the metastable concentration range, the premicellar aggregates should have macroscopic lifetimes and small polydispersity.

The work has been done by Radina Hadjiivanova (PhD student).

Correlated motion of membrane inclusions
Proteins embedded in bilayer membranes, or particles embedded in fluid monolayers, move in a correlated way due to flows that their motions induce within the sheet and in the surrounding liquid. In addition, their presence in the layer modifies its response to stresses – its effective viscosity – much like the way colloid particles modify the viscosity of a 3D suspension. We have derived the coupling diffusion coefficients of pairs of such inclusions, along with their dependence on the concentration of inclusions and the effect of that concentration on the response of the embedding membrane.

How does a vesicular capsule swell? As the number of molecules making the membrane increases (curves from bottom to top), the swelling with the number of encapsulated particles approaches criticality (top black curve). These theoretical curves are highly universal – i.e., they can be made to fit a large variety of vesicles and encapsulated solutions.
The work has been done by Naomi Oppenheimer (PhD student). It is supported by the Israel Science Foundation.

References:
Our research is focused on the development of new methodologies for the preparation of nanostructured novel composite materials by protein mediated biotemplating. The research program is divided into two arms: The first is focused on the use of single, soluble protein molecules as core for biotemplating leading to biologically active molecular protein-metal hybrids. The second is focused on the use of stabilized protein crystals as biotemplates for the fabrication of novel composite materials by ‘filling’ their 3D intermolecular voids arrays with organic or inorganic materials.

In the first arm we developed a new approach to direct electroless deposition of silver and palladium to the surface of the enzyme glucose oxidase (see Figures 1&2 and [1, 2]). The resulting enzymatically active soluble hybrids were successfully nano-wired to platinum electrode allowing glucose determination in the absence of oxygen (a study carried out in collaboration with Prof. Y. Shacham-Diamand from the Faculty of Engineering and Prof. J. Rishpon from our faculty. The silver-glucose oxidase hybrid was also used as a new antibacterial agent to combat biofilms by enzymatically attenuated in situ silver release [3]. The methodology developed for the production of silver-enzyme hybrids was recently successfully applied for the preparation of avidin-silver hybrid (Mor et al. (2008), manuscript in preparation).

In the second arm we continued our study aiming at the establishment of methodologies for the monitoring of the ‘filling’ process of a protein crystal biotemplate [4] with elucidation of the mechanism of chemical crosslinking of protein crystal by glutaraldehyde – a prerequisite for biotemplating without distortion – and resolution of its end products by x-ray analysis [5], a study carried out in collaboration with Prof. F. Frolov and demonstrated the construction of a 3D metal nanoparticles array formation within the crystals voids array (see figure 3 and [6]).

To gain control on the voids array of the protein crystal biotemplate we have recently concluded three projects: in the first the capability to alter the geometry of the crystal’s voids array by chemical modification of the protein ‘building block’ with purification of the modified protein prior to crystallization (Cohen-Hadar et al., manuscript in preparation); in the second the use of co-addition of modifying agents into the crystallization medium was demonstrated.

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**Figure 1:** High Resolution Electron Microscope (Philips Tecna F20) micrographs, obtained without staining for silver-glucose oxidase hybrid. The chemical identity of the silver deposit was confirmed by EDX (inserts).

**Figure 2:** High Resolution Electron Microscope (Philips Tecna F20) micrographs, obtained without staining for palladium-glucose oxidase hybrid. The chemical identity of the palladium deposit was confirmed by EDX (inserts).
(Lagziel-Simis et al, manuscripts in preparation) and in the last, the use of site directed point mutations (Wine et al, Submitted).

References:

Figure 3: Scanning electron microscope photographs (X50,000-300,000) showing the 3D array of silver grains formed within the pores of stabilized ConcanavalinA crystal.
Cancer diagnostics, by nanotechnology based biosensor that profiles tissues acoustically.
Dr. Ludmila Buzhansky

Malignant tissue characterized in its unique viscoelastic and metabolic properties, as well as express on its surface characterized molecular markers, which varied in their type and quantity due to the tumor type and phase. These viscoelastic, metabolic and molecular cancerous transformations, affect the acoustic profile of the tissue. Amendis had designed and patented the Bio-SoNaR (biological acoustic nano resonator), an innovative nanofabricated bio-sensor that enables the sensing of tissue's acoustic profile. In our lab we tested the device and proved that the Amendis’s Bio-SoNaR can acoustically profile a live, intact, malignant tissue. In the future, Amendis will combine the Bio-SoNaR along with advanced algorithmic code. This combination will save the need for biopsy and will enable non-invasive, irradiation free and accurate diagnosis of cancer, in real-time and in a harmless manner to humans and their environment.

Electronic Characterization of self assembled peptide nanotubes via atomic force microscopy based methodologies
Nadav Amdursky, PhD student

The use of atomic force microscopy (AFM) based methodologies enable us to explore the electronic characterization of material in nanometric resolution and in non invasive way, unlike other techniques which cannot yield high resolution results such as photoemission techniques. In this work we focus on two main techniques; electrostatic force microscopy (EFM) and Kelvin probe force microscopy (KFM) to characterize the electronic properties of peptide nanotubes (PNT). The researched PNT are well ordered, long and hollow nanotube made by self assembly of COOH-Phe-Phe-NH₂ (FF) building blocks.
Where as the EFM scans can tell us about the capacity and the dielectric constant of the nanotubes, the KFM provide us important information about the energy levels of the nanotubes. At recent years, a great effort has been invested in the corporation of peptide nanotubes at the micro-, nano-electronics industry, such as in the field of diagnostics and biosensing, field effect transisors (FET), micro-electro-mechanical system (MEMS), solar cells and more. The performance of such devices can be improved by unraveling the electronic and energetic structure of the nanotubes. By knowing the work function of the nanotubes we can go half way and design in a more intelligent and logical way devices which involve electrons or holes movement from or to the nanotube.
With the described techniques we were able to conclude about the electrostatic polarizability and the high dielectric constant the nanotubes possess. Moreover, a new understanding of the energy levels of the nanotubes was obtained by discovering their work function.
In our future plans we will continue to research the physical properties of several self assembly peptide nanostructures (such as peptide hydrogels and nanospheres). The physical properties include photoluminescence, excitonic states, piezoelectric and paraelectryc properties of the peptide nanostructures.

Peptide-Based Hydrogels
Ron Orbach MSc Student

Hydrogels are frequently used as 3D scaffolds to support the growth of cultured cells for tissue engineering and regeneration. A variety of natural polymers may be used as hydrogel-forming materials. These polymers are appealing for medical use owing to their similarity to the natural extracellular matrix (ECM), which allows cell adhesion while maintaining very good biocompatible and biodegradable properties. Peptide-based hydrogels exhibit the advantages
of both synthetic and naturally derived hydrogel forming materials. They are easy to manufacture in large quantities and can also be easily decorated chemically and biologically.

Our group has previously reported the efficient self-assembly of the Fmoc-Phe-Phe (Fmoc-FF) into a rigid hydrogel with remarkable physical properties. In order to gain a better insight and identification of novel materials for biomedical use we (in collaboration with Dr. Dror Seliktar – Technion) characterized the self-assembly of eight new different Fmoc-peptides into various structures with distinctive molecular and physical properties. Each of these novel nanostructured materials are formed under mild conditions in an aqueous solution using low-molecular weight building blocks. In most cases, their properties enable utilization in different biomedical applications including drug delivery, tissue engineering and tissue regeneration, due to their biocompatibility and assembly into 3D networks. Following in-vitro studies we recently began to study the peptide-based hydrogels in-vivo (in collaboration with Prof. Ari Barzilai and Dr. Arie Solomon – TAU and Prof. Smadar Cohen - BGU). Moreover, using this Fmoc-peptide library we study the role of aromatic groups in regulating the self-assembly process, and consequently influencing the structural and physical properties of the resulting hydrogels. Self-assembly is a promising technique in the formation of nano-materials. By using bio-physical techniques we intend to investigate more deeply the aromatic effect on this process and to further explore the hydrogels potential at in-vivo systems.

**Diphenylalanine Peptide Nanotubes as a reinforcement agent**
Even Nitzan MSc student, Adler-Abramovich Lihi PhD student

Indentation type experiments using an atomic force microscopy revealed impressive mechanical properties of the diphenylalanine peptide nanotubes. It was found that they maintain high averaged point stiffness of 160 N/m, and correspondingly high Young’s modulus of approximately 19 GPa, which places these peptide nanotubes among the stiffest bio-inspired materials presently known. Inspired by these findings we have decided to create composite material integrated with the peptide nanotubes in order to create new reinforced materials. Since peptide nanotubes are biocompatible, they can be used to reinforce materials and implants in medical use such as dental material and bone grafting substitutes. The initial tests will examine the reinforcement effect of peptide nanotubes on epoxy. The tension and compression properties of the epoxy and nanotube/epoxy composites will be measured using standard tests (American Society for Testing and Materials D638-99) and dogbone models.

**The use of self assembled peptide nanostructures to encapsulate magnetic nano-particles**
Inbal Yanai MSc Student

Lose of cerebral neural cells is observed in several age-associated disorders such as Alzheimer’s disease, Parkinson’s disease and other neurodegenerative disorders. Currently, the medical procedures for the diagnosis of those diseases are not very conclusive. The need for new methods is relevant now more than ever with...
longer life expectancy and the increase of the elderly population. The work at our laboratory of the mechanism of self-assembly had led to the discovery of aromatic dipeptides that self assemble into various structures such as nanotubes, nanospheres and others. These structures are well-ordered and discrete. The ongoing research is directed towards the development of novel contrast agents to produce magnetic resonance imaging (MRI) based on peptide nanostructures loaded with ferromagnetic nano-particles. The experimental model includes short peptides which self assemble into closed caged nanospheres under certain reaction conditions and encapsulate the magnetite nano-particles during the self-assembling process. In order to develop efficient diagnostic tool the nanospheres will be decorated with recognition motifs that could specifically bind antigens that are associated with various degenerative diseases. The formation and stability of the nanospheres was investigated in various tests at different conditions. The nanospheres have been successfully decorated with amyloid beta recognition motif and with biotin- streptavidin gold in order to show that the chemistry didn’t affect the spheres and to visualize the attachment of the gold particle on the nanospheres surface.

**Characterization, controlled assembly and patterning of aromatic dipeptides nanostructures**  
Adler-Abramovich Lihi PhD student

Organic and inorganic self-assembled tubular nanostructures were suggested to have key potential in nanotechnological devices and applications. Several studies have shown the possible use of bionanometric material for applications ranging from molecular electronic to drug delivery. The diphenylalanine peptide, the core recognition motif of the Alzheimer’s Beta-amyloid polypeptide, efficiently self-assembles into discrete, well-ordered peptide nanotubes. In the current research, using different microscopy and spectroscopy tools we describe a remarkable thermal stability of aromatic dipeptide nanotubes (ADNT) both in aqueous solution and under dry conditions. In addition, the peptide nanotubes exhibit substantial chemical stability in various organic solvents as acetone or acetonitrile. Furthermore, we studied the peptide nanotubes mechanical properties, which were directly measured by indentation type experiments using an atomic force microscopy. Moreover, we explored the potential of a self-immolative dendritic system to serve as a transporter platform for control assembly of the peptide nanostructures. Self- immolative dendrimers are a novel class of molecules that can amplify a single cleavage event, which is received at a focal point, into multiple releases of tail groups at the periphery. Additionally, we used the inkjet technology for the application of peptide nanostructures on non-biological surfaces. The ADNT which self assemble readily in solution were used as an „ink“ and patterned on transparency foil and ITO plastic surfaces using a commercial inkjet printer. In summary, the remarkable thermal, chemical and mechanical durability and the ability to pattern and control the assembly of the peptide nanotubes suggests their application in conventional microelectronic and microelectromechanics processes, as well as fabrication into functional nanotechnological devices.
The main research direction in this period focused on self-organization of silicide nanocrystals on vicinal Si surfaces. Results of our work (two papers in press) have indicated, that under certain conditions, self-assembled heteroepitaxial CoSi$_2$ nanocrystals not only preferentially decorate the step-bunch edges on a vicinal Si(111) surface, which by itself is not a new phenomenon, but their mean size and separation distance along the ledges is also dictated by the parent step-bunch height. Such a self-organization produces one-dimensionally ordered nanostructure arrays, and locally, where the terrace width is comparable with the nanocrystal-nanocrystal separation distance – even two-dimensionally ordered patterns result (see Figure below). These results imply that functional self-assembled and self-ordered nanostructure arrays can be non-lithographically fabricated bottom-up on the properly miscut and prepared vicinal substrates (e.g. 4°-5°), by carefully choosing the deposit materials (and hence the heterosystem, e.g. Co/Si) and selecting the desired deposition method (e.g. solid-phase epitaxy) and parameters.

Hence, currently three topics are being investigated, at the M.Sc. level, in this respect: (a) substrate self-patterning by controlling not only the miscut angle, but also by choosing an azimuthal miscut direction, and varying the magnitude and the polarity of the flash current, (b) the self-organization phenomenon itself, on such self-patterned substrates, by varying the deposition methods and parameters, as well as the heterosystem (e.g., Co/Si, Ti/Si, etc.), and (c) electronic properties of the self-ordered nanostructures themselves, such as the local density of states (LDOS) by scanning tunneling spectroscopy (STS). Up until now, these projects have been at the M.Sc. level and have been partly funded by short-term grant schemes (such as by the US Air Force). However now, due to winning a 4-year ISF personal grant on this topic, this research is going to be significantly boosted, both in terms of funding and duration, as well as in terms of manpower and quality (collaboration with another experimental (Kaplan, Technion) and theoretical (Rabani, TAU) groups, and raising the level to doctoral or even post-doctoral level).

On top of this achievement, continuation of the work on the Ge/Si nanocrystals has lead to an additional publication in Physical Review Letters, second in two years. There are two additional topics studied in the lab, namely the investigation of surface effects in contact formation to CZT crystals, at the Ph.D. level (funded by the ISF), and a newly contemplated X-sectional STM/STS studies of multilayered compound-semiconductor superlattices (funded by the industry). Finally, two more topics begin to materialize in the laboratory: “Spintronics & magnetic nanostructures” in collaboration with G. Markovich, at a post-doc level, and “Characterizations of multilayered structures by STM and KPFM” at a Ph.D. level (in collaboration with Y. Rosenwaks).
Increasing exposure of biological systems to hydrophobic pollutants, such as polycyclic aromatic hydrocarbons and various nanomaterials, is of great public concern. Organisms have an array of biological defense mechanisms and it is believed that mucosal gel (which covers the respiratory system, the gastrointestinal tract, etc.) provides an effective chemical shield against a range of toxic materials. However, the mechanisms and portals of entry of water-insoluble materials into various biological systems are yet to be fully understood. In the present work, we demonstrate that a representative mucin glycoprotein, Bovine Submaxillary Mucin (BSM), has impressive and unprecedented capabilities for binding and solubilizing of water-insoluble materials and nanoparticles in physiological solution. Our results provide a unique example to a route of how hydrophobic materials could be solubilized in a biological system and what could be the first biochemical interface between such materials and living organisms. Combustion of wood, coal, liquid fuels and domestic and industrial waste results in emission of enormous amounts of polyaromatic hydrocarbons (PAHs) and carbon nanoparticles into the atmosphere. In contrast to PAHs, which are well known as powerful mutagens and carcinogens, the biological effects (transport, bio-accumulation and toxicity) of various nanomaterials have only begun to be explored. It is expected that an array of biological defenses should protect the organisms from these materials. For example, it is believed that the mucosal gel that covers the respiratory and gastrointestinal tracts should provide an effective physical and chemical shield against a range of toxic materials. The primary components of mucus are high-molecular weight mucin glycoproteins that form numerous covalent and non-covalent bonds with other mucin molecules. The condensed and complex microstructure of the mucus network gives rise to a highly visco-elastic gel that significantly impedes the transport rates of large macromolecules and nanoparticles. The fast rate of mucosal exchange offers an effective natural protective and disposal mechanism for various potentially toxic exogenous materials.

Our study was focused on preparation of a series of BSM complexes with anthracene (Ant), benzo[a]pyrene (Bap), coronene (Cor), C_{60}-fullerene (C_{60}), fullerene-like WS_{2} (IF-WS_{2}) and multi-walled carbon nanotubes (MWNT) ligands. UV-vis and fluorescence spectra that were measured for each of the separated BSM-ligand complexes revealed unprecedented capabilities of a salivary glycoprotein to bring into aqueous solution various organic and inorganic water-insoluble materials. All UV-vis spectra of the obtained complexes demonstrated superimposition of characteristic BSM peaks with absorbance peaks clearly belonging to chromophores of the bound ligands. We found that the BSM-complexed Ant, Bap, Cor and C_{60} chromophores exhibited line-broadening and bathochromic shifts when compared to spectra of the non-complexed ligands in chloroform. The UV-vis spectrum of the BSM-complexed Ant essentially preserved its well-resolved features, strongly suggesting that the protein is bound to a monomer of this PAH. In contrast, lost of fine structure in spectra of the BSM-complexed Bap and Cor chromophores may indicate that these larger ligands are bound to BSM in a form of π-π stacked dimers or even larger aggregates. The spectrum of BSM-complexed C_{60} characterized by broad absorbance bands, unambiguously showed that this ligand is bound in a form of clusters. To the best of our knowledge, this is the first demonstration of a IF-WS_{2} complex with any host and the first stable dispersion of this nanomaterial in solution. The UV-vis spectrum of the BSM-complexed MWNT closely resembled reported spectra for the nanomaterial dispersion in aqueous solutions. Complexation modes of the evaluated ligands were further investigated using three-dimensional excitation-emission fluorescence spectroscopy. No fluorescence was detected for BSM complexes with C_{60}, IF-WS_{2} and MWNT. We found that BSM-complexed Ant, Bap and Cor exhibited significant decreases...
in fluorescence intensity. We observed bathochromic shifts in maximum emission wavelengths from 15 nm (for Ant and Bap) to 55 nm (for Cor) as compared to fluorescence spectra of non-complexed ligands in chloroform solutions. Despite the shift, the fluorescent spectrum of BSM-complexed Ant had most of the well-resolved features of the free ligand. In contrast, significant changes were observed in the shapes of the fluorescence spectra of the bound Bap and Cor relative to the spectra of the chloroform solutions of the free ligands. We believe that in the case of Cor ligand, the large red shift in the maximum emission of the complexed Cor could not be attributed only to solvatochromism. Supporting our interpretation of the UV-vis spectroscopy results that Cor binds as an aggregate, fluorescence data strongly indicate that discotic Cor ligands are bound to BSM glycoprotein in the form of π-π stacked clusters. Further characterization and evaluation of overall sizes of the BSM complexes were performed using dynamic light scattering (DLS) and high performance size-exclusion liquid chromatography (SEC). We found that in phosphate buffer solution the native BSM glycoprotein was present in two populations. The SEC chromatogram of the BSM was characterized by two partially overlapping peaks at 18.5 and 15.8 min. DLS measurements indicated that the one population was comprised of species with a median hydrodynamic radius (Rh) of 4 nm, a size that corresponds to the monomeric unit of the BSM protein with reported molecular weight of 170 KDa. The second population was comprised of larger species with a broader range of sizes (Rh of 70 nm), indicating presence of BSM in a form of oligomers.

SEC analysis of Ant-BSM complexation products showed formation of larger aggregates not found in the native BSM protein chromatogram. A fraction of the population had retention times similar to those observed in the chromatogram of BSM; however, most of the material eluted at retention times of 11.3 and 8.4 min, corresponding to higher molecular weight species. The chromatogram monitored at 390 nm, a wavelength at which only the Ant chromophore is observed, revealed that most of the Ant ligand was located in these new products and only a small amount of the ligand was bound by species corresponding in size to the native BSM. DLS analysis of the Ant-BSM complexation products showed two relatively narrow populations of species. The smaller sized species with Rh of 10 nm are presumably BSM dimers, whereas the larger species with Rh of 120 nm correspond to oligomers of BSM and to Ant-BSM complexation products. SEC analysis of Bap-BSM complexation products also showed formation of large size products. The chromatogram monitored at 280 nm showed that although a considerable population of species had the same elution time as the BSM protein, a significant portion of the material eluted at retention times of 13.5 and 8.4 min. The SEC chromatogram monitored at 390 nm (wavelength at which only the Bap chromophore is observed) revealed that although the Bap ligand was present in all species, the host-to-ligand ratio in larger entities was substantially higher than in species that eluted at 15.6 min. The DLS analysis of Bap-BSM complexation products indicated the presence of two major and one minor population of species. The lower molecular weight species, with Rh of 4 nm, were attributed to monomers of BSM and the larger species, with Rh values of 21
and 179 nm, correspond to Bap-BSM complexation products. The Cor and C_{60} complexes with BSM gave similar results. SEC analyses of these complexes showed practically complete transformation of the starting BSM protein into larger, ligand-loaded entities. The DLS analysis of Cor- and C_{60}-BSM complexation products also showed a presence of one major population with R_h values of 140 and 180 for Cor and C_{60}, respectively. The DLS and SEC results for Ant, Bap, Cor and C_{60} ligands provided very important and complementary data to supplement our UV-vis and fluorescence spectroscopy findings.

Although there are various modes by which smaller hydrophobic ligands such as Ant and Bap can be bound inside small hydrophobic cavities formed by BSM protein, larger cluster-forming compounds such as Cor and C_{60} have large hydrophobic surfaces that require a different mode of binding for their solubilization. In the latter mode, several BSM oligomers are recruited for “coating”, creating submicron-size nanostructures. It should be mentioned that practically all available BSM is participating in the dissolution process. In contrast to that of C_{60}-fullerene, SEC analysis of IF-WSe_2-BSM complexation showed formation of two products. The chromatogram, monitored at 280 nm, shows that although the major species eluted at the same time as BSM protein, a certain population eluted at retention time of 8.5 min. The chromatogram monitored at 550 nm revealed that the WSe_2 ligand was present in both products. The host-to-ligand ratio in species that eluted at 8.4 min was substantially higher than in species that eluted at 16.2 min. The DLS analysis also showed the presence of two populations of species. The species with R_h of 10 nm was attributed to BSM dimers and the larger species, with R_h of 180 nm, probably corresponds to nanoparticles comprised of a hydrophobic IF-WSe_2 cluster core coated by several BSM oligomers.

We expected that, like C_{60}-fullerene, MWNT would form relatively large aggregates, binding all available BSM protein. However, results of both DLS and SEC analyses clearly demonstrated that only a fraction of the available BSM protein participated in complexation. The SEC chromatogram, monitored at 280 nm, showed that although a considerable fraction of the species elute at times equivalent to those observed for BSM protein alone, a significant portion of the material eluted at a retention time of 8.4 min. The SEC chromatogram monitored at 550 nm, at which only the MWNT was observed, revealed that majority of the MWNT ligand was in the complex with the larger radius. The DLS measurements showed presence of two populations of species: a smaller sized species (R_h of 10 nm) and larger species (R_h values in range of 180-290 nm and higher); these species are presumably various length MWNTs and their bundles coated with a layer of BSM.

We have demonstrated that a representative mucin protein, bovine submaxillary mucin, has impressive capabilities for binding and solubilizing water-insoluble materials and nanoparticles in physiological solution. Different modes of binding were observed for the hydrophobic compounds tested. The larger C_{60}-fullerene and coronene molecules bound to BSM in a form of clusters, whereas smaller anthracene and benzo[aj]pyrene exhibited significantly lower degrees of aggregation. Interestingly, the BSM glycoprotein was also capable of unbundling carbon nanotube aggregates. The ability of mucins to solubilize otherwise water-insoluble materials in a physiological solution suggests that these proteins may function as the first biochemical interface between living organisms and polyaromatic hydrocarbons and various nano-materials.
In the past several years we have developed new methods for neuronal cell patterning and recording using nano topography realized by islands of high density fabrics made of carbon nanotubes (CNT). Carbon nanotube coated surfaces are biocompatible, and are excellent surfaces for cell growth and thus are excellent candidates to be used to interface man-made substrates with biological systems. In the past year we focused on improving our understanding on the surface-cell interaction and the understanding of mechanical mechanisms taking place during the organization of the cells. The bio-physical aspects were explored using staining and microscopy methods. By investigating cell-CNT interaction we were able to revisit issues related to network patterning. In particular we recently described the role of tension as an important parameter in setting neuronal networks (NNs) structure. We are currently engaged in new collaborations exploring the benefits of CNT neuro-electrodes for retinal interfacing applications. We also explore chemical approaches to further enhance the performances of these electrodes. Preliminary data show markedly high S/N recordings from whole mount retina, with conspicuous increase in recorded signal suggesting improved coupling. Additional activity of our lab concerns the integration of CNT with silicon based MEMS devices. We have recently been able to work out a scheme how to achieve such integration using simple, scalable means.

References:
3. Ze’ev R. Abrams, Zvi Ioffe, Alexander Tsukernik, Ori Cheshnovsky, and Yael Hanein, A Complete Scheme for Creating Large Scale Networks of


We study the dynamics of the interactions of proteins with nanoscale lipid domains in the membranes of live cells, and with specialized nanostructures (focal adhesions) that function in cell motility and signaling. We developed biophysical methods based on fluorescence recovery after photobleaching (FRAP) to study the interactions of signaling proteins (e.g., Ras oncogenic proteins) with the plasma membrane and of focal adhesion plaque proteins with the focal adhesions in live cells.

The two main nano-related research directions during this period have focused on:

(1) The membrane anchorage of Ras proteins, especially the highly oncogenic constitutively active K-Ras(G12V) mutant, and its modulation by the cationic amphiphilic drug chlorpromazine (CPZ) (one paper in press). These studies have revealed the mechanism by which this drug is able to selectively detach from the plasma membrane oncogenic proteins such as K-Ras, by interfering with their attachment to the membrane via interactions of polybasic cluster of amino acids in their tails. This results in alteration of the localization of K-Ras within nanodomains, reduces its affinity to the plasma membrane, and leads to redistribution to internal organelles such as mitochondria or endosomes. Depending on the organelle that the activated K-Ras is translocated to, the cells are either induced to undergo apoptosis (when K-Ras is in the mitochondria) or are growth-arrested (endosomal localization) by CPZ. These findings have a potential for the future development of therapeutic approaches to counteract oncogenic K-Ras activity.

(2) Factors regulating the molecular dynamics of focal adhesions (a manuscript is now in preparation). These studies are conducted in collaboration with Prof. Benjamin Geiger (Weizmann Institute) and Prof. Joseph Klafter (School of Chemistry, Tel Aviv University). Focal adhesions are specialized membrane-associated multi-protein complexes that link the cell to the extracellular matrix and play crucial roles in cell-matrix sensing. However, the regulation of FA dynamics is largely unknown. We conducted interdisciplinary studies combining biophysics (FRAP studies on live cells), mathematical modeling (in silico simulation studies) and cell biology studies to show that four dynamic states of focal adhesion proteins (paxillin and vinculin) exist: an immobile fraction bound to focal adhesions, a fraction associated with these nanostructures that undergoes exchange, a juxtamembrane fraction experiencing attenuated diffusion, and a fast-diffusing cytoplasmic pool. The juxtamembrane region surrounding FAs displays a gradient of focal adhesion plaque proteins with respect to both concentration and dynamics. We propose that this juxtamembrane domain can act as an intermediary layer, enabling fast regulation of focal adhesion formation and reorganization.
Solid Nano-Particles in Liquid Nano-Containers

Solid/liquid two-components Ga-Pb structures in isolated nanometer sized particles have been produced and studied by electron microscopy. The production, based on the breath figure technique, was obtained at Nice University (Prof. R. Kofman’s group), while Transmission Electron Microscopy was obtained at Tel-Aviv University.

The movement of the solid nano-particle in the liquid nano-container, seen in fig. 1, was analyzed quantitatively and was found as non random movement. The influence of temperature on the interaction (wetting) with the container’s walls was studied.

Characterization of Materials at Nanometer Scale by Electron holography

Characterization of ferro-electric domains was obtained by Dr. Cheuk-wai Tai (a post doc from Hong-Kong). Characterization of electric-fields in ferro-electric nano-particles was obtained by Daniel Szwazmann (a student, supervised in collaboration with Gil Markovich). Characterization of Carbon soot was obtained in collaboration with Dr. M. Pawlyta (a visitor from Poland). Fig. 2, taken from Daniel Swarzmann’s work, shows the dependence of ferro-electric electric field on the particle’s size.

Obtaining corrected atomic scale images

Due to lens aberrations the conventional high resolution images are limited to indicate the spacing between atomic planes, however the exact location of atoms are difficult to be interpreted. Overcoming this problem is obtained by acquisition series of images at different defocus conditions and reconstruction of “True Image”. The relevant software was purchased and the procedure is being studied being studied by applying the method into two relevant problems:

3.1. Defect analysis in nano particles of HfO2. In previous study, Gil markovich and Einat Tirosh proposed that in these crystals, magnetic
properties are correlated with crystallographic defects. Accordingly, the method of “True Image” is being used (by Dr. Check-wai TAI) for quantitative analysis the defects including strain mapping in their surround.

Conductivity in Granular Al:Ge System. During the 80’s an intensive study on various aspects of conductivity in granular Al:Ge was obtained by Guy Deutscher’s group. In view of the advanced electron microscopy methods available nowadays, the system is re-examined. Fig. 3 demonstrates a case of “soft contact” between two Al grains.

Fig. 3: A “soft contact” between Al nano-crystals embedded in amorphous Ge
**Cancer**

(1) **The novel formulation of paclitaxel in tumor-targeted carriers (gagomers), denoted TX/GAG.** The achievements of building these novel formulations and investigating their structural properties and *in vitro* activities were summarized in the 2006-2007 report. During 2008 this novel formulation was tested *in vivo* against the conventional formulation of detergent-solubilized free drug denoted TX/Cre, in mice bearing solid tumors. The major achievements are:

- (a) TX/GAG as well as the carrier itself (i.e., drug free gagomer) are safe *in vivo*
- (b) TX/GAG, unlike TX/Cre is long-circulating and provides active drug targeting to the tumor and
- (c) Treatment with TX/GAG slows down tumor progression significantly with indications of trend-turn to tumor regression, whereas upon treatment with TX/Cre tumor progression increases exponentially. This novel formulation merits further development towards clinical studies.

(2) **Hyaluronan bioadhesive liposomes as tumor-targeted carriers for diagnostics and treatment of brain tumors.** This project was initiated in 2008, *in vitro*, utilizing the 9L and the C6 cell lines (both originating from rat brain tumors). The major findings are:

- (a) Unique to these brain-tumor cell cultures, CD44 receptors to which the carriers are targeted, are present not only on the cell membranes but also on the fibrillar connections between cells (figure 1A).
- (b) The targeted nano-liposomes (denoted ULV-HA-BAL) bind with high affinity to the tumor cells and the intercellular fibers, significantly better than the non-specific adherence of the conventional non-targeted nano-liposomes (denoted ULV-RL). This was determined qualitatively (figure 1B, C) and quantitatively – an affinity ratio of 16/1 was found for the tumor-targeted vs. the non-targeted, liposomes.

**Diabetes**

A therapeutically-effective oral insulin formulation is a not-yet-achieved primary goal in diabetes treatment. In this project nano-sized insulin fibrils were formed inside the muco-adhesive gagomer particles (figure 2). The major findings are:

- (a) The novel insulin formulation, denoted gagomeric-insulin, was stable in media simulating the environments within the Gastrointestinal tract
- (b) In an *in vitro* bioassay it was verified that the gagomeric-insulin formulation can release active insulin monomers.
- (c) Selecting a well-known diabetes mouse model (Streptozotocin-induced) to test the novel insulin formulation, critical needs was found to further develop this model and the experimental protocols for testing novel diabetes treatments and controls. These needs were successfully addressed and can now be of assistance to others in the field.
- (d) Under conditions that mimic human eating habits, a single dose of the novel formulation given orally reduced blood glucose levels significantly, quite equivalent to the conventional treatment of subcutaneous injection, with a later onset but significantly longer duration. Oral administration of free insulin had no effect. These results indicate the novel insulin formulation has high potential to perform as long-acting insulin, meriting further investigation. Moreover, forming nano-fibrils inside gagomers may emerge to be a general approach for oral administration of therapeutic proteins.
Inflammatory diseases

Macrophages, phagocytic cells that are major constituents of defense mechanisms, stimulate the immune system to secrete both pro- and anti-inflammatory cytokines. Unregulated release of pro-inflammatory cytokines may lead to chronic auto-immune inflammatory diseases. Hyaluronan (HA), and its receptors (CD44) when expressed on macrophage membranes, may have key roles in macrophage activities and may also be used for anti-inflammatory therapeutic approaches utilizing targeted hyaluronan-nanocarriers. The relationships among CD44, HA and macrophage activities in the inflammation arena still need molecular elucidation. Macrophages are also known to endocytose particles such as liposomes and spheres, which is detrimental for drug carriers designated to deliver drugs to receptors on cell membranes. Current findings are: (a) Expression of CD44 receptors on macrophage membranes was verified for the macrophage cell line RAW264.7. Extending such studies, CD44 was also found in membranes of primary macrophages, and on both young and mature RAW264.7 cells. (b) Macrophages bound, with high affinity, both regular (RL) and hyaluronan (HA-BAL) liposomes, but with a distinct critical difference: The RL were endocytosed (figure 3A), while the HA-BAL remained bound to their receptors at the cell surface (figure 3B). This is clear experimental support that the latter, but not former, are eminently suitable to perform their designated role as carriers of drugs that stimulate secretion of anti-inflammatory cytokines.
The Markovich group focuses on studies of various types of physical phenomena related to inorganic nanocrystals. In the last year the group has been working on several nanocrystal systems:

**Preparation of two-dimensional magnetic nanocrystal arrays and studies of their magnetic and spin-polarized electron transport properties with emphasis on their magnetization dynamics**

Magnetite (Fe₃O₄) nanocrystal monolayers were produced using the Langmuir-Blodgett technique and deposited on various substrates. In one study, the films were deposited in small gaps between two electrodes defined by electron beam lithography. Magneto-transport measurements revealed relatively large magnetoresistance values (10-25%) at temperatures >200K and their magnetic field and temperature dependence indicated the dominance of inter-particle tunneling in the contribution to the measured magnetoresistance.

In a second study, a multilayer film was deposited on a gold film and studied by a variable-temperature, ultra-high vacuum scanning tunneling microscope. In this project, temperature dependent noise in the tunneling current was observed and correlated to the dynamics of magnitic moment switching of the nanocrystals.

**Studies of defect induced ferromagnetism in oxide nanocrystals, such as HfO₂**

In this project, colloidal HfO₂ nanocrystals were produced using thermal decomposition of organometallic precursors in a high boiling point organic solvent. It was found that by tuning synthesis conditions, i.e., type of solvent and surfactants, temperature, the concentration of defects in the nanocrystals could be controlled, turning a small part of the nanocrystals into ferromagnetic for the higher defect concentrations. Currently, a high-resolution electron microscopy study, performed in collaboration with Cheuk-Wai Tai and Yossi Lereah is aimed at identifying the exact nature of these defects and defective nanocrystals.

**Studies of the interactions of chiral molecules with surface plasmon excitations of noble metal nanoparticles**

We have used colloidal silver nanoparticles, in the size range of 10-50 nm to enhance the absorption of chromophore molecules, attached through a short tri-peptide (glutathione) to the particles’ surfaces. The absorption of the chromophores, in resonance with the surface plasmon excitation of the silver particles, was enhanced by about two orders of magnitude. In addition, we have studied the circular dichroism induced at the achiral chromophore molecules by attachment to the chiral peptide. This weak circular dichroism response was also enhanced by two orders of magnitude on binding to the silver particles.

**Studies of nanoscale ferroelectricity in BaTiO₃ nanocubes**

Ferroelectric BaTiO₃ nanocubes in the size range of 20-100 nm were synthesized and studied by x-ray diffraction, Raman spectroscopy and transmission
electron microscopy, in particular with electron holography, a technique that is able to image the ferroelectric polarization fields within the nanocrystals with nanometric resolution. These studies revealed nanocrystal size dependence in the polarization fields, as well as insight into the polarization behavior near the nanocrystal surfaces.

**Deposition of metal nanowire films on surfaces using colloidal chemistry**

A technique for the deposition of very thin films containing networks of high aspect ratio gold/silver nanowires has been developed. The technique involves the preparation of a growth solution containing a mixture of gold and silver salts and a reducing agent in the presence of high concentrations of surfactant molecules. After its preparation the solution is spread on various surfaces with a controlled thickness and then let dry. While drying the surfactant molecules form tubular template structures in which the metal nanowires grow. These nanowire network films are highly conductive, as well as transparent due to the low volume filling of the nanowires.
In our research laboratory at the Department of Condensed Matter we currently conduct experimental research related to nanoscience in the following three directions:

**Superconductor proximity effect in ferromagnetic and normal junctions**
We investigate the superconductor critical current through nano-size ferromagnetic layers. The theoretically predicted spin screening effects in S/F nanostructures are studied by both transport and optical methods.

**One-dimensional quantum wires and mesoscopic effects**
Electronic transport properties are studied at low temperatures in V-grooved quantum wires. The quantization of the conductance as a result of one-dimensional band structure is observed. The dephasing in 1D is studied.

**Metal-superconductor quantum phase transition in nanocylinders**
Our experimental groups in collaboration with the colleagues in WIS developed a new technology to fabricate superconducting nanocylinders with the diameters as small as 50 nm. The quantum phase transition is investigated in these structures.

**Achievements:**
The theory based on the formation of the π-junction in Josephson coupled structures containing ferromagnetic layers was verified and the oscillations of the critical current versus the thickness of F-layer were observed.
The predictions of Luttinger liquid theory were verified and the value of the interaction constant for GaAs was deduced from the Luttinger model.
Little-Parks oscillations were observed in 100 nm Nb cylinders.

Three invited lectures on the above subjects were presented at the in the international scientific meetings and conferences in Leiden (Holland), Kharkov (Ukraine), Crete (Greece).

**Reference:**
During the years 2007-2008 my group worked on the following direction:

1. New approaches for the synthesis of multicomponent nanoparticles and the applications.
2. The synthesis and characterization of a new family of Si and Si/Ge highly controlled nanotubular structures. We are currently applying this nanotubular structures in biosensing and nanofluidic studies.
3. The development of photovoltaic future devices based on nanoscale light collectors arrays.
4. The development of highly efficient fuel cells of ultra-low cost based on cheap nanocatalyst elements.
5. Biosensing of a broad range of diseases based on large scale nanowires-based FET arrays.
6. The development of novel approaches for the assembly of ultra-large arrays of nanowires elements.
The major research efforts have been focused on the development of nanomaterials for 3D-lithium-ion microbatteries (3DMB) and fuel cells. 3D-interlaced (3D-IMB) and 3D-concentric microbatteries (3D-CMB) consist of tens of thousands of multi microcells connected in parallel within a half mm thick non-conducting perforated high-aspect-ratio silicon or glass substrate. TAU research group has recently developed and demonstrated the first working prototype of a rechargeable 3D-concentric lithium ion microbattery with amorphous MoO$_x$S$_y$ cathode*. A semi-3DMB-on-Si cell demonstrated less than 0.1% capacity loss over 100 successive cycles with 100% DOD. A semi-3DMB-on-MCP cell with a composite cathode (20 min of deposition) exhibited about 10 mAh/cm$^2$ reversible capacity, 20 to 30 times that of a similar footprint, 2D cell. The key challenge in the improvement of 3DMBs performance is the development of new nanosize electrode and electrolyte materials with highly percolating particle distributions and short ion diffusion distances. These materials are essential to provide four major characteristics required for powering of new mobile electronic and implantable medical devices: high energy and peak power, fast charge, long cycle life and safe behavior.

Within the frame of the current research nanoporous silicon membranes have been prepared by DRIE and metal assisted anisotropic etching. It was found that increase of the HF concentration is followed by the decrease of pore size; hydrogen peroxide increases pores dimensions; addition of ethanol promotes uniformity of the porous silicon layer. The nanoporous membranes (Fig.1) demonstrate potential to be used as Li$^+$ conducting media for 3D-interlaced microbatteries. After optimization of etching process the conductivity, being a function of pore size and tortuosity, is expected to approach that of commercial polymer membrane. The Li$^+$ conduction mechanism is under investigation.

Electrochemical and structural study of electrodeposited thin-film nanoparticle copper sulfide (Cu$_2$S and CuS) cathodes for 3D-CMBs has been carried out. According to the SEM data, the deposition parameters, such as time of deposition, current density, temperature of the electrolytic bath, stirring rate and addition of PEGDME and PEI additives, affect the morphology of the copper sulfide films. Planar and 3DCMB cells with nanoparticle copper sulfide cathodes are under testing.

* A nano-battery technology developed at Tel Aviv University could pose the sought for solution for fast charge/discharge safer batteries that reduce the fire hazards recently reported in connection with Lithium based mobile batteries (NY Times August 15th, 2006).

Fig.1: SEM images of nanoporous interlaced Si with incompletely etched partition between microcontainers
The main research direction in this period focused on several directions: (i) development of novel molecular-based transistors, (ii) demonstration of large-area bio-inspired solar cell and (iii) development of new type of bio-compatible materials.

**Molecular-based Transistors.**
Recently, we have demonstrated a new type of molecular transistor. This Central – Gate Molecular Vertical Transistor (C-Gate Molvet) exhibits nm-scale channel length, ambipolar behavior and is extremely sensitive to gate voltage. Using this device we have successfully demonstrates a molecular-quantum switch, protein-based transistor, and tunable-hysteresis devices.

**Large-area bio-inspired solar cell**
Several years ago we have demonstrated the fabrication and operation bio-inspired Solar-cell devices. This was done by introducing into microcavity arrays Photo-System I (PSI)-based nanoparticles. These nanoparticles were found to convert photons to photovoltaic energy with reasonable yield. A device made out of PSI-based SAM sandwiched between top transparent conducting electrode and bottom gold electrode yielded several percents energy conversion efficiency. On the last year we have focused some efforts on up-scaling of the active area of this Cell. This task is very challenging since the nm-sized PSI layer could be easily damaged during the up-scaling process. Recently, we have successfully fabricated a 0.01Cm² solar cell with several percents yield. The task was achieved after a special type of conducting polymer was incorporated in the solar cell serving as a mediator between the sensitive bio-particles and the solid state template.

**Water soluble biomaterials**
One of the great challenges in material science is to produce water soluble inorganic materials. These types of materials, usually hyrdophbic in nature, are required for various applications such as bio-compatible materials and plastic electronics. Recently, M. Gozin (TAU), have shown that certain types of water soluble biological compound can “swallow” hydrophobic compounds. We have used this phenomenon to construct a water soluble biocompatible glue (figure 3). This composite material contains a conducting polymer serving as a mediator between the sensitive bio-particles and the solid state template.

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1. In collaboration with Prof. Chanoch Carmeli, Biochemistry, TAU
2. In collaboration with Dr. Michael Gozin, TAU

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**Figure 1:** Examples of Transfer characteristics of the C-Gate Molvet. Left. Protein-based C-Gate MolVet operated at low power and showing high gate sensitivity. Inset. Transfer properties in amibipolar mode. Right – Switching device. A Negative differential resistance peak can be created (left) or erased (right) by application of the appropriate gate voltage.

**Figure 2:** Prototype of the 0.01Cm² PSI-based solar cell showing ~2% yield.
Glue is composed of carbon nanotubes incorporated inside biological matrix. Our preliminary results indicate that this material is unique by its adhesion and mechanical properties.

Figure 3: Biocompatible water soluble glue. Left-Transmission Electron Microscopy (TEM) image of Nanotube network is incorporated in biological matrix. Right. High resolution image of the single wall nanotubes located inside the composite material.
We further exploited nanoparticles modified electrodes for increased sensitivity. We have utilized the unique electronic properties of carbon nanotubes (CNT) and peptide nanotubes (PNT) in electrochemistry as means of promoting the electron transfer and as a substrate for binding and adsorption of reactive components. CNT and PNT were attached to carbon electrodes and employed as sensitive bioelectrochemical sensors. The electrode surface with and without CNT taken with is shown below:

In particular we concentrated in:

1. Detection of heavy metals by differential pulse anodic stripping

2. Electrodes modified with CNT and PNT were used in a sensitive detection of pollutants. The enzyme tyrosinase was immobilized on the electrode and used for the detection of phenolic compounds. The amplifying effect of the nanoparticles is clearly envisaged below.

3. The synergistic effect of combining both nanoparticles was also examined and the results are shown below: It is evident that electrodes modified with PNT and CNT produced the highest signal.
4. CNT attached to electrodes were also exploited in highly sensitive electrochemical enzyme immuno-sensors for medical diagnostics. Hormones, viruses antibodies for viruses and disease markers were tested. For example an immunosensor for progesterone was developed and measured in milk. Also an immunosensor for C reactive protein (CRP) a protein that is a marker for heart failure and acute inflammation was developed and measured in human serum samples. The effect of the nanoparticles is evident, especially at low concentrations.

5. Screen print electrode modified with carbon nanotubes were used for the monitoring of formaldehyde released from brain cancer cells in response to anti cancer pro-drug treatment.
New Generation of Energy Storage Devices Based on Peptide Nanotubes

In cooperation with Prof. E. Gazit

Supercapacitors are promising energy storage devices due to their unique combination of high power density and relatively large energy density. We report on environmentally clean bio-supercapacitors based on peptide nanotubes (PNT)-modified electrodes. Short aromatic dipeptides can self-assemble into ordered structures at the nano-scale. These assemblies include nanotubes, nanospheres, nano-plates and hydrogels with nano-scale order (Reches, Gazit, Science, 2003; Nature Nanotechnology, 2006, 2007). Peptide nanotubes represent a novel class of nanotubes of biological origin as an appealing alternative to carbon nanotubes. It has been observed that these biological nanostructures possess paramount properties of different origin allowing to find at the intersection Biology-Physics-Engineering new advanced nanotechnological applications using the PNT building blocks.

The basis for the new nanotechnology presented in this report is recently developed new biomolecules deposition method which allows to drastically change the previous PNT deposition technology, based on peptide evaporation from aqueous or organic solutions. The method may be applied to PNT coatings on unlimited area with high density and homogeneity, controllable thickness as well for fabricating patterned PNT structures.

We found that vertically oriented peptide nanotubular bio-inspired structures demonstrate new surprising physical properties such as dielectric, electrochemical, and wettability which affords to develop environmentally clean nanodevices. A new PNT-based technology has been applied to development of ‘green’ energy storage devices—Supercapacitors. Deposition of PNT arrays on carbon electrodes strongly increases efficiency of these electrochemical units due to high density PNT coating. In the developed electrostatic supercapacitors aromatic vertically oriented dipeptide nanotubes have been used for modification of carbon electrodes of supercapacitors. The conducted studies show that PNT-modified electrodes demonstrate pronounced rectangular shape voltammograms and possess a high double-layer capacitance exceeding that parameter for carbon nanotubes-coated electrodes.

Bio-Inspired Nanostructures Light Sources

In cooperation with Prof. E. Gazit

We discover pronounced quantum confinement (QC) and photoluminescence (PL) phenomena in self-assembled peptide nanostructures of different origin diphenylalanine (FF) nanotubes deposited by a vapor deposition method, hydrogels self-assembly of short Fmoc (N-fluorenylmethoxycarbonyl)-based molecules into fibrous formation, nanospheres self-assembled from Fmoc-FF or Boc-(Di-tert-butyl dicarbonate)-FF monomers and natural self assembly of amyloidogenic proteins. Our observation of QC effects is a direct evidence of highly ordered sub-nano-crystalline areas embedded in the structures. The observed PL of the bio-nanotubes opens a new nanotechnology field of bio-inspired materials for optical devices such as biosensors, LED, biolasers and more.
Prof. Rosenwaks' group is developing and implementing new methods for measuring the electronic properties of semiconductor materials and devices with nanometer spatial resolution. The various techniques are based on scanning probe microscopy in general and Kelvin probe microscopy (KPFM) in particular.

**Nano Research projects:**
- AFM tip– Semiconductor electrostatic interaction.
- Nanoscale electrical characterization of operating semiconductor devices.
- High Voltage AFM.
- UHV-KPFM of QDs and dopants in III-V semiconductors.
- Organic self-assembled monolayers on semiconductor.
- Bio Field Effect Transistors.
Research on the deposition of nano scale interconnects for Ultra Large Scale integration (ULSI) and for nano electrodes. The research scope included basic research of nano scale metal alloys like CoWPB using a novel surface adsorption model that had been developed in TAU and the super filling of nano scale trenches by Cu.

In the nano electrode field we are active in the following projects: a. The ReNaChip Project - Brain –machine hybrid for the rehabilitation of a discrete motor learning function. Investigation in manufacturing of electro-analytical cell with sensing nano-electrodes. b. The SmartHand project – developing nano electrodes for a new hand prosthesis, c. TOXICHIP – bioluminescent technology for detecting toxicity in water and d. DipChip – electrochemical technology for detection of toxicity in water. Additionally we have a research project under the Magnet program for developing nano electrodes on plastic for MEMS applications.

Corporation with Industry and other universities in Nano issues

1. The SmartHand project: Tyndall Institute, Ireland, Aalborg University, Denmark, ARTS Lab and CRIM Lab, Scuola Superiore Sant’Anna, Pisa, University Hospital, Malmö, Sweden, Lund University, OSSUR inc (Iceland)
2. The ReNaChip Project. UNEW (Newcastle University, UK), UPF (Spain), G.Tec (Austria), Lund University (Sweden),
3. DipChip: the University of Koblenz (Germany).

Corporation within TAU

Corporation with: Prof. Matti Mintz (Applied Psychology), Prof. H. Messer-Yaron (Eng.), Prof. J. Rishpon, Prof. A. Freeman and Prof. E. Gazit (Life Science), Prof. D. Benayahu (Medicine),
We developed a new therapeutic strategy for bone neoplasms using combined targeted polymer-bound angiogenesis inhibitors. We conjugated the aminobisphosphonate alendronate (ALN), and the potent anti-angiogenic agent TNP-470 with N-(2-hydroxypropyl) methacrylamide (HPMA) copolymer. Previous work on caplostatin, a HPMA copolymer-TNP-470 conjugate, demonstrated that polymer conjugation of TNP-470 increases its half-life, water-solubility and tumor accumulation, while reducing its toxicity. Using reversible addition-fragmentation chain transfer (RAFT) polymerization, we synthesized a conjugate of HPMA copolymer-ALN-TNP-470 bearing a cathepsin K-cleavable linker, a protease overexpressed in bone tissues. Free and conjugated ALN-TNP-470 demonstrated their synergistic anti-angiogenic and antitumor activity by inhibiting proliferation, migration and capillary-like tube formation of endothelial and osteosarcoma cells. Our bi-specific conjugate reduced vascular hyperpermeability and remarkably inhibited human osteosarcoma growth in mice by 96%. HPMA copolymer-ALN-TNP-470 is the first narrowly dispersed anti-angiogenic conjugate synthesized by RAFT polymerization that targets both the tumor and endothelial compartments warranting its use on osteosarcomas and bone metastases.

Targeting bone metastases with a novel bi-specific anticancer and anti-angiogenic polymer-alendronate-taxane conjugate

Bone metastases are one of the main obstacles for the recuperation of prostate cancer patients and in most, if not all, cases the reason why the disease becomes non-curable and devastating. At advanced stages of bone metastases, the disease progresses to a phase when the standard systemic therapy progresses to a highly chemotherapy-resistant state. Therefore, new strategies for the treatment of advanced metastatic disease need to be rapidly developed. The taxane paclitaxel and the bisphosphonate, alendronate are two drugs used as treatment for bone metastatic prostate cancer. However these two drugs, when given at the standard doses cause side effects. Furthermore, patients treated with paclitaxel develop at a certain point drug resistance. In the past few years, there is growing evidence that taxanes and bisphosphonates have antiangiogenic properties. It has been found that paclitaxel at ultra low dose is antiangiogenic. It is conceptually accepted that angiogenesis inhibitors alone may not be sufficient to eradicate prostate cancer. Therefore, the generation of a combination of drug delivery systems with bi-specific antiangiogenic and antitumor properties is a novel approach. We developed a new strategy of targeted therapy for the treatment of prostate cancer bone metastases. Our strategy rests upon the conjugation of a bone targeting moiety, the aminobisphosphonate alendronate, and the chemotherapeutic agent paclitaxel to N-(2-hydroxypropyl) methacrylamide (HPMA) copolymer. Water-soluble HPMA copolymers accumulate in tumor tissues due to the enhanced permeability and retention effect. Taking advantage of the multivalency of polymers, we conjugated both drugs on the same polymeric backbone resulting with a nanoconjugate at a size of ~100 nm. Paclitaxel was conjugated to HPMA copolymer through the dipeptide phenylalanine-lysine-p-aminobenzyl carbonate linker. This linker was cleaved by the lysosomal enzyme cathepsin B overexpressed in tumor epithelial and endothelial cells and free paclitaxel was released. HPMA copolymer-paclitaxel-dipeptide-alendronate nanoconjugate inhibited the proliferation of prostate carcinoma cells. Furthermore, our conjugate demonstrated anti-angiogenic effect on different steps of the angiogenic cascade such as proliferation, migration and tube-formation of endothelial cells.

Our goal with the new synthetic conjugate of HPMA copolymer-paclitaxel-dipeptide-alendronate will be “specificity with reduced toxicity”. It is
anticipated that specific targeted therapies will improve quality of life for patients and will provide an alternative to patient’s refractory to taxane-based therapies, avoiding toxicities.

**Targeting αvβ3 integrin on tumor vasculature using a novel polyglutamic acid-paclitaxel conjugate with the divalent peptide E-[c(RGDFK)₂]**

Angiogenesis, new capillary blood vessel growth from pre-existing vasculature, is a critical factor in cancer progression. Therefore, anti-angiogenic therapy, alone or in combination with conventional cytotoxic therapy, may be a promising therapeutic approach. Paclitaxel is a potent cytotoxic insoluble drug; however, it is hydrophobic and causes side effects such as neutropenia, neuropathies, and when solubilized in Cremophor EL causes hypersensitivity reactions. Polyglutamic acid (PGA)-paclitaxel is currently undergoing phase three clinical trials showing promising results. PGA is a water-soluble, non-toxic and biodegradable polymer that accumulates in the tumor bed by the enhanced permeability and retention (EPR) effect when it is used at a nano-scaled size of 10-100 nm. Here, we conjugated PGA with paclitaxel and a targeting moiety, the cyclic RGD peptidomimetic, E-[c(RGDFK)], which actively targets the conjugate to proliferating tumor endothelial cells overexpressing αvβ3 integrin. The resulting PGA-[c(RGDFk)]₂-paclitaxel nanoconjugate measured at a diameter size of ~30 nm. The ester linker between the polymer and the drug is hydrolytically labile and paclitaxel release occurred under lysosomal acidic pH and the PGA itself was degradable by lysosomal enzymes such as cysteine proteases, particularly cathepsin B. PGA-E-[c(RGDFK)]₂-paclitaxel inhibited the proliferation of endothelial cells, their attachment to fibrinogen-coated wells, their migration towards vascular endothelial growth factor (VEGF) and their formation as capillary-like tubes. These results warrant our conjugate as a novel targeted anti-angiogenic anticancer therapy.

**References**

**Papers**


**Book Chapters**


2. Miller KA and Satchi-Fainaro R, Polymer Therapeutics: From novel concepts to clinical applications, In

**Patents:**
In collaboration with the group of Prof. Ori Cheshnovsky we have developed a novel method to detect heating and cooling processes in current carrying molecular junctions. The experimental approach is based on Raman scattering measurements of junctions under bias. The effective temperature of the various modes are calculated from the Anti-Stokes/Stokes ratio signals for each mode. We have also developed a novel synthesis approach to metal nanowires. The resulting nanowires have an aspect ratio of 1:10,000. The nanowires are grown inside the pores of polycarbonate membranes. The novelty in the process is that the wires are grown in a “meat grinder” fashion. Under certain conditions as the nanowires grow they are also continuously pushed out of the membranes into the surrounding solution by means of a self-electrophoretic process. The rate of the latter process is identical to the rate of elongation and as a consequence, the reduction of ions takes place only within the pores, thus maintaining a uniform diameter. As a result, while the membranes are only 6μm long, the formed nanowires could be two orders of magnitude longer. This new synthetic approach is important first because it is intriguing in terms of the fundamental processes involved, and second because it opens new routes to fabricate one-dimensional nano-scale materials with very high aspect ratios.

We have demonstrated how segmented Au-Ni nanowires can be highly effective thermocouples with spatial resolution of few nanometers and temporal resolution in the microsecond range. The performance of the devices is characterized by a self-heating procedure in which an ac heating current at ω frequency is applied on the wires while monitoring the resulting thermoelectric voltage $V_{th}$ at 2ω using a lock in technique. An analytical model has been developed that enables to determine the time response of the thermocouples from plots of $V_{th}$ as a function of ω. We have also developed a new method to form Metal Quantum Point Contacts (MQPCs) with quantized conductance values in the range of 1-4$G_0$. The contacts appear to be stable at room temperature for hours and can be deterministically switched between conductance values, or reform in case they break, using voltage pulses. The method enables to integrate MQPCs within nano-scale circuits to fully harness their unique advantages.

**References:**

5. Fabrication of highly stable configurable metal quantum point contacts, Itach N., Yutsis I., Selzer Y., Nano Lett. 2008 ASAP.
We have conducted a number of research programs that qualify as nano-science and nano-technology related.

We have carried out

- Experimental studies of nano-layers of organic molecules at semiconductor surfaces. Some of the work has been done in collaboration with HMI, Berlin, Germany.
- Theoretical work related to the studies mentioned above in collaboration with WIS.
- Characterization project nano-layers of oxides and high-K gate stacks on Si and SiC nano-scale devices and developed a physical model of these systems.
- Studies of photocatalysis on nano-crystalline layers of titanium dioxide.
- Studies of nano-scale resolution imaging of the electronic structure at semiconductor surfaces by SEM.

References:

From nano-scale single synapse to information processing in neural networks

It is widely believed that memory is grounded in synaptic connections. However, the principles regulating encoding, storage and retrieval of information in synaptic networks remain elusive. Our research is focused on the endogenous mechanisms controlling memory capacity in adult brain. Our main target is to determine how the quality and quantity of ongoing neuronal activity affect the properties of individual pre- and post-synaptic compartments, neural connections (few synapses) and synaptic networks (thousands of synapses). To fulfill this goal, we are applying combination of electrophysiology, functional quantitative imaging, spectroscopy, biochemistry, and molecular biology. Our recent results indicate that uncorrelated pattern of neuronal activity plays a key role in synaptic network organization and memory function.

Endogenous amyloid-β proteins:
from single-protein interactions to physiological and pathological functions

It is generally agreed that accumulation of cerebral Aβ leads to synapse loss, the best structural correlate of cognitive deficits in Alzheimer’s disease (AD). However, physiological functions of endogenous Aβ peptides which are secreted by neurons through life still need to be identified. Furthermore, pathological processes leading to Aβ-mediated synaptic failure remain controversial. In this project we aim to determine the casual relationships between the pattern of neuronal activity, release of endogenous Aβ, and the number and plasticity of synapses in wild-type hippocampal neurons. This is achieved by using high-resolution optical imaging to detect vesicle release and plasticity at the level of individual presynaptic terminals, electrophysiology to monitor input-output relationships at the level of neuronal connections, FRET-based spectroscopy to estimate dynamics of protein-protein interactions, and biochemistry to measure APP-derived species in hippocampal culture. Our findings suggest that elevation in ongoing neuronal activity coupled to reduction in synapse capacity to transfer bursts might initiate compensatory synapse loss and subsequent memory decline in AD.

This project is supported by New Investigator Award in Alzheimer’s Disease of American Federation for Ageing Research, Morasha-ISF program, and National Institute for Psychobiology.
Regulation of Hebbian plasticity by optimization of the GABA$_{\beta_1\alpha}$ receptor activity

A persistent challenge in unraveling mechanisms that regulate memory function is to bridge the gap between inter-molecular dynamics of single-proteins and behavior of single synapses in neuronal networks. In particular, the mechanisms linking dynamics of presynaptic G-protein-coupled receptors to plasticity of synaptic connections under physiological conditions are poorly understood. In this project we intend to determine relationships between the pattern of neuronal activity, inter-molecular interactions within the GABA$_R$ signaling complex, and plasticity of presynaptic terminals in hippocampal pyramidal neurons. This is achieved by using real-time simultaneous measurements of molecular dynamics, transmitter release, and presynaptic plasticity at the level of individual presynaptic terminals. We examine possible interactions between presynaptic GABA$_R$s, G protein subunits, and Ca$_2^+$ channels at resting state using fluorescence resonance energy transfer (FRET) methods. The degree of coupling between the proteins is tested as function of terminal location, transmitter release probability, and GABA$_R$-mediated tonic inhibition using activity-dependent FM styryl dyes. The proposed research will elucidate basic principles underlying protein-protein interactions within the presynaptic GABA$_R$ signaling complex and their role in regulating presynaptic activity.

This project is supported by BSf and ISf programs.

References:
3. I. Vertkin and I. Slutsky. Optimization of the GABA$_{\beta_1\alpha}$ receptor activity maintains Hebbian plasticity of presynaptic terminals (submitted).
Prof. Michael Urbakh

Dynamics in Small Confining Systems

**Atomic scale friction**
We focus on a molecular level description of processes occurring between and close to interacting surfaces which is needed to first understand, and later manipulate friction. Methods for controlling friction using mechanical and chemical approaches are introduced.

**Single Molecular Force Spectroscopy**
Dynamic force spectroscopy provides an ability to measure adhesive interactions at the single-molecule level with unprecedented resolution, and to achieve deeper insight in the underlying mechanisms of molecular processes without the “scrambling” that occurs due to ensemble averaging. To both explore the results of force spectroscopy experiments and to reveal a molecular scale energy landscapes, we establish relationships between equilibrium properties of the nanoscale systems and the characteristic features measured under non-equilibrium conditions.

**Molecular Scale Engines**
We have introduced a new approach to build microscopic engines on the microscopic and mesoscopic scales that move translationally or rotationally and can perform useful functions such as pulling of a cargo. Characteristic of these engines is the possibility to determine *dynamically* the directionality of the motion. The approach is based on the transformation of internal vibrations of the moving object into directed motion, making use of the nonlinear properties of friction.

**Electrochemically Variable Optics**
We have introduced novel electrowetting systems containing an interface between two immiscible electrolytic solutions (ITIES) that can change its shape under a small voltage variation, which are two orders of magnitude lower than in conventional systems. Our research focuses on modeling ITIES-based electrically tunable optical devices: (i) variable-focus lenses, (ii) variable mirrors based on reversible adsorption of metal nanoparticles on droplets, and (iii) optical filters based on quantum dots localized at ITIES.

**References:**
The following 41 researchers are currently involved in nano related research activity and use the facility and the support of the nano center:

The following list of publications includes much coauthoring of TAU researchers and is presented as a single comprehensive list of 150 papers.

1. **Targeted filamentous bacteriophages as therapeutic agents**

2. **Antibacterial nanomedicine**

3. **A Two-State Electronic Antigen and An Antibody Selected to Discriminate Between These States**

4. **Targeted drug-carrying bacteriophages as anti bacterial nanomedicines**

5. **Targeted anti bacterial therapy**

6. **Targeted Bacteriophages as Therapeutic Agents**

7. **Killing cancer cells by targeted drug-carrying phage nanomedicines**

8. **Potential of Antibacterial Nanomedicines**

9. **Solid lubricants on textured surfaces obtained by pulsed air arc treatment**

10. **Magnetic properties of carbon nano-particles produced by a pulsed arc submerged in ethanol**

11. **Ni–C powder synthesis by a submerged pulsed arc in breakdown mode**

12. **Photosynthetic Reaction Center Covalently Bound to Carbon Nanotubes**

13. **Photovoltaic activity of photosystem I-based self-assembled monolayer**

14. **Fabrication of Serially Oriented Multilayers of Photosystem I Proteins on Solid Surfaces by Auto-Metallization**

15. **Photoelectric Junctions Between GaAs and Photosynthetic Reaction Center Protein**
    Frolov, L.; Rosenwaks, Y; Richter, S; Carmeli, C; Carmeli, L, J. Physical Chemistry. C. 112 (35), pp 13426-13430. 2008.

16. **Dirty Superconductivity in the Electron-doped cuprate \( \text{Pr}_2\text{Ce}_2\text{Cu}_3\text{O}_8 \): Tunneling study**
17. Hole superconductivity in the electron-doped superconductor Pr$_x$Ce$_{2-x}$CuO$_4$

18. Field-induced nodal order parameter in the tunneling spectrum of YBa$_2$Cu$_3$O$_7-x$

19. A spatial interpretation of emerging superconductivity in lightly doped cuprates

20. Polar Kerr Effect Measurements of YBaCuO: Evidence for Broken Symmetry Near the Pseudogap temperature

21. Observation of Andreev – Saint-james reflections in nano-scale planar superconductor to ferromagnet contacts

22. Field-induced nodal order parameter in the tunneling spectrum of YBaCuO superconductor

23. Long-range hydrodynamic response of particulate liquids and liquid-laden solids

24. Critical swelling of particle-encapsulating vesicles

25. Swelling of particle-encapsulating random manifolds

26. POSS-Polyimide Nanocomposite Films: Simulated Hypervelocity Space Debris and Atomic Oxygen Effects

27. The Use of SIMS in Quality Control and Failure Analysis of Electrodeposited Items Inspected for Hydrogen Effects

28. Enzymatically attenuated in situ release of silver ions to combat bacterial biofilms: a feasibility study

29. Towards Hall Effect Spintronics

30. Linear positive magnetoresistance and quantum interference in ferromagnetic metals

31. Extraordinary Hall effect in Co-Pd bilayers

32. Perspective of spintronics applications based on the Extraordinary Hall Effect (Invited review)

33. Offset reduction in Hall Effect measurements using a non-switching Van der Pauw technique

34. In-plane and out-of-plane shape transitions of heteroepitaxially self-assembled nanostructures

35. Step-mediated size-selection and ordering of heteroepitaxial nanocrystals

36. Mechanical tuning of two-dimensional photonic crystal cavity by micro electro mechanical flexures

37. CoWBP capping barrier layer for sub 90 nm Cu interconnects
38. Real space identification of the CZT(110) surface atomic structure by scanning tunneling microscopy

39. Self-organization of cobalt-silicide nanoislands on stepped Si(111)

40. A Novel Fullerene-NMDA-Receptor Antagonist Compound Reduces Axonal Loss and Neurological Disability a Model of Progressive Multiple Sclerosis

41. Multipeak negative-differential-resistance molecular device

42. Bio-delivery of Fullerene Derivative

43. Can Apomyoglobin Form a Complex with a Spherical Ligand? Interactions between Apomyoglobin and [C_{60}]fullerene derivative

44. A Complete Scheme for Creating Predefined Networks of Individual Carbon Nanotubes

45. Integrating peptide nanotubes in micro-fabrication processes

46. Iron assisted growth of copper-tipped multi-walled carbon nanotubes

47. Electro-chemical and biological properties of carbon nanotube based multi-electrode arrays

48. Formation of polyaniline layer on DNA by electrochemical polymerization
Bardavid Y., Ghabboun J., Porath D., Kotlyar A. B., Porath D. 2008 Polymer, 49, 2217-2222

49. High-resolution STM imaging of novel single G4 DNA molecules

50. Assembling of G-strands into novel tetra-molecular parallel G4-DNA nanostructures using avidin-biotin recognition

51. Specific and efficient adsorption of phosphorothioated DNA on Au-based surfaces and electrodes

52. Radiationless Transitions of G-Wires and dGMP

53. Versatile Binding Sites of β-Lactoglobulin

54. Phage therapy as a solution for antibiotic resistance of bacteria
58. Directed Metallization of Single Enzyme Molecules with Preserved Enzymatic Activity

59. Protein Crystal-Mediated Biotemplating

60. Carbon nanotube micro-electrodes for neuronal interfacing

61. A Dissipative Particle Dynamics Model of Carbon Nanotubes

62. Differential interference of chlorpromazine with the membrane interactions of oncogenic K-Ras and its effects on cell growth

63. Molecular analysis of recombinase-mediated cassette exchange reactions catalyzed by integrase of coliphage HK022

64. Preparation and analysis of a two components breath figure at the nano scale

65. Size effects on Melting and Wetting in the Ga-Pb Nano-Alloys
Marco Allione, Richard Kofman, Franck Celestini and Yossi Lereah, Presented in XIV Int Symp. on Small Particles and Inorganic Clusters (isspic 14), will be published in the relevant book/journal.

66. Phason dynamics in nonlinear photonic quasicrystals

67. Nonlinear dynamics of nanomechanical and micromechanical resonators

68. Nonlinear photonic quasicrystals for novel optical devices

69. Classical to quantum transition of a driven nonlinear nanomechanical resonator

70. Insights into modeling Streptozotocin-induced diabetes in ICR mice

71. Control and prevention of bacterial infections in burns by new formulations based on drug/carrier systems

72. Treatment of resistant human colon cancer xenografts by a fluoxetine-doxorubicin combination enhances therapeutic responses comparable to an aggressive bevacizumab regimen

73. Tuning Colloidal Syntheses to Control Co2+ Insertion in Ferrite Nanocrystals

74. Plasmon Resonance Enhanced Absorption and Circular Dichroism
75. Scanning Tunneling Spectroscopy study of Temperature Dependent Magnetization Switching Dynamics in Magnetic Nanoparticle Arrays

76. Dipolophoresis of nanoparticles

77. A unified theory of dipolophoresis for nanoparticles

78. Electro convection about conducting particles

79. Boundary effect in electro-magnetic-phoresis

80. Macro-scale description of transient electro-kinetic phenomena over polarizable dielectric solids

81. Nuclear Coupling and Polarization in Molecular Transport Junctions: Beyond Tunneling to Function

82. Theory of light-induced current in molecular-tunneling junctions excited with intense shaped pulses

83. Inelastic effects in molecular junction transport: Scattering and self-consistent calculations for the Seebeck coefficient

84. Molecules take the heat (Perspective)

85. Cooperative effects in molecular conduction

86. Inelastic effects in molecular junctions in the Coulomb and Kondo regimes: Nonequilibrium equation-of-motion approach

87. Molecular Transport Junctions: Vibrational Effects

88. Heat conduction in molecular junctions

89. Quantum phase transition in ultra small doubly connected superconducting cylinders

90. Resonant Tunneling of Electrons in Quantum Wires (Review)

91. Inverse proximity effect in superconductor-ferromagnet bilayer structures

92. Electroless plating of silicon nitride using (3-aminopropyl) triethoxysilane

93. Electrochemical lab on a chip for high-throughput analysis of anticancer drugs efficiency

94. Electrochemical Biosensors for pollutants in the environment

95. An Electrochemical Immunosensor for C-Reactive Protein based on Multi-walled Carbon Nanotube-Modified Electrodes
96. Interface modification and bonding of lithium tantalate crystals

97. Interface engineering and direct bonding of Lithium tantalate crystals

98. Patterned arrays of ordered peptide nanostructures

99. Electron-induced surface reactivity modification in Zinc oxide-based thin films

100. Electronic Characterization of Si(100)-Bound Alkyl Monolayers Using Kelvin Probe Force Microscopy

101. Measurements of the Einstein relation in doped and undoped molecular thin films

102. Charging of thin dielectric Films Following Focused Ion Beam Irradiation

103. Electrostatics Properties of Molecular Gated BioFETS

104. Distinguishing between dipoles and field effects in molecular gated transistors


106. Coupled Lasers Rotation Sensor (CLARS)

107. Direct rotation-induced intensity modulation in circular Bragg micro-lasers

108. Secure key generation using an ultra-long fiber laser: transient analysis and experiment


110. Fabrication and characterisation of “on-edge” junction for molecular electronics

111. Synthesis of very high aspect ratio metal nanowires by a self-propelling mechanism

112. Segmented nanowires as nanoscale thermocouples

113. Fabrication of highly stable configurable metal quantum point contacts

114. Controlled patterning of peptide nanotubes and nanospheres using inkjet printing technology

115. Bioactive nanostructures branch out

116. Patterned Arrays of Ordered Peptide

117. The role of the 14-20 domain of the islet amyloid polypeptide in amyloid formation
118. Cognitive Performance Recovery of Alzheimer’s Disease Model Mice by Modulating Early Soluble Amyloidal Assemblies

119. The Effect of rf-Irradiation on Electrochemical Deposition and its Stabilization by Nanoparticle Doping

120. Tumor Cytotoxicity and Endothelial Rac Inhibition Induced by TNP-470 in Anaplastic Thyroid Cancer

121. Dramatic drug-release enhancement with an elimination-based AB, self-immolative dendritic amplifier

122. Malignant progression and blockade of angiogenesis in a murine transgenic model of neuroblastoma

123. In vitro and in vivo evaluation of doxorubicin conjugates with the divalent peptide E-[c(RGDFK)2] that target integrin αvβ3

124. Design and Development of polymer conjugates as antiangiogenic agents, Special Theme issue: Polymer Therapeutics: Clinical Applications and Challenges for Development

125. In vitro evaluation of paclitaxel conjugates with the divalent peptide E-[c(RGDFK)2] that target integrin αvβ3, International Journal of Pharmaceutics

126. The resurrection of the first synthetic angiogenesis inhibitor

127. Polymer Therapeutics: From novel concepts to clinical applications, In Wiley Encyclopedia of Chemical Biology

128. Polymer Enzyme Liposome Therapy. HPMA copolymer-phospholipase C and Dextrin-phospholipase A2 as model triggers, European Journal of Pharmaceutics and Biopharmaceutics

129. In vitro evaluation of paclitaxel conjugates with the divalent peptide c(RGDfK)2 that target integrin αvβ3, International Journal of Pharmaceutics

130. XPS and TOFSIMS study of electrodeposited molybdenum oxysulfide cathodes for lithium and lithium-ion microbatteries

131. A novel Proton-Exchange Membrane based on single-step preparation of functionalized ceramic powder containing surface-anchored sulfonic acid
132. **Drying-Mediated Hierarchical Self-Assembly of Nanoparticles: A Dynamical Coarse-Grained Approach**


134. **Constructing Spin Interference Devices from Nanometric Rings**

135. **Long-Range Electronic to Vibrational Energy Transfer in Nanocrystals**

136. **Negative Differential Spin Conductance by Population Switching**

137. **Theory of Resonance Energy Transfer Involving Nanocrystals: The Role of High Multipoles**

138. **Magneto-Resistance of Nanoscale Molecular Devices Based on Aharonov-Bohm Interferometry**

139. **Distribution of carrier multiplication rates in CdSe and InAs nanocrystals**

140. **Probing microscopic origins of confined subdiffusion by first-passage observables**

141. **Analyzing friction forces with the Jarzynski equality**

142. **Fluorescence recovery after photobleaching: The case of anomalous diffusion**

143. **Temporal correlation functions of concentration fluctuations: An anomalous case**

144. **Fluorescence correlation spectroscopy (FCS): The case of anomalous diffusion**


146. **Comparative study of human erythrocytes by digital holographic microscopy, confocal microscopy, and impedance volume analyzer**

147. **Giant Stark effect in quantum dots at liquid/liquid interfaces: A new option for tunable optical filters**

148. **Torque and Twist against Superlubricity**

149. **Understanding voltage-induced localization of nanoparticles at a liquid–liquid interface**

150. **Controlling microscopic friction through mechanical oscillations**

151. **Critical size for intracluster proton transfer from water to an anion**
152. Interactions at tetraphenyl-porphyrin/InP interfaces observed by surface photovoltage spectroscopy

153. Monolithic rare-earth doped sol-gel tapered rib waveguide laser

154. SPR waveguide sensor based on combined sensing of phase and amplitude changes - art. no. 64750R

155. Surface plasmon interferometer in silicon-on-insulator: novel concept for an integrated biosensor: comment

156. Application of the laser capture microdissection technique for molecular definition of skeletal cell differentiation in vivo.

157. Comparative study using scanning electron techniques for imaging of micro-architecture and antigen appearance.

158. Cell-based screening for membranal and cytoplasmatic markers using dielectric spectroscopy

159. Site localization of membrane-bound proteins on whole cell level using atomic force microscopy
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<td>2. System for Determining Endothelial Dependent Vasoactivity, 7374541  Giora Amitzur, Eli Zimerman - Medicine; Shmuel Eina, Eran Peleg - Engineering</td>
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<td>3. Controlled Enzymatic Removal and Retrieval of Cells, 7364565  Amihay Freeman-Life Sciences</td>
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<td>5. Fuel Cell with Proton Conductive Membrane and with Improved Water and Fuel Management, 1410453  Emanuel Peled, Tair Duvdevani, Arnon Blum, Vladimir Livshits, Adi Aharon-Exact Sciences</td>
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<td>6. Method and Apparatus for Treating Tumors Using Low Strength Electric Field, 7395112  Yona Keisar, Rafi Korenstein, Igor Entin-Medicine; Yosef Rosenberg</td>
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<td>9. Optoelectronic Device and Method of Manufacturing Same  Chanoch Carmeli, Itai Carmeli, Ludmila Frolov-Life Sciences; Shachar Richter-Exact Sciences; Yossi Rosenwaks-Engineering; Alexander Govorov</td>
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<td>10. Optoelectronic Device and Method of Fabricating The Same  Chanoch Carmeli, Itai Carmeli, Ludmila Frolov-Life Sciences; Shachar Richter-Exact Sciences; Yossi Rosenwaks-Engineering</td>
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<td>13. Photonic Crystal Resonator, A Coupled Cavity Waveguide, and A Gyroscope  Ben Zion Steinberg, Amir Boag, Jacob Scheuer-Engineering</td>
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<td>15. Electro-Optical Modulator and Method of Fabricating The Same  David Mendlovic, Damian Goldring-Engineering</td>
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<td>16. Modified Optical Resonator Structure  David Mendlovic, Damian Goldring-Engineering</td>
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40. A HPMA-Alendronate-TNP-470 Conjugate Comprising A High Load of Alendronate and Uses Thereof in The Treatment of Bone Related Angiogenesis Conditions
Ronit Satchi-Fainaro, Ehud Segal-Medicine, Jindrich Kopecek, Pavla Kopeckova, Pan Huazhong

41. Conjugates of A Polymer, A Bisphosphonate and An Anti-Angiogenesis Agent and Their Use in The Treatment and Monitoring of Bone Related Diseases
Ronit Satchi-Fainaro, Keren Miller-Medicine, Doron Shabat-Exact Sciences, Rotem Erez-Exact Sciences

42. Novel Polymers Comprising An Anti-Angiogenesis Agent and RGD or An Analog Thereof and Uses Thereof in The Treatment of Angiogenesis Related Diseases
Ronit Satchi-Fainaro-Medicine, Maria Jesus Vicent Docon

43. Compounds Suited as Nanocarriers for Active Agents and Their Use
Ronit Satchi-Fainaro-Medicine-Sackler Faculty, Paula Ofek-Life Sciences, Rainer Haag

44. Antiangiogenic Polymer Therapeutics and Use Thereof
Ronit Satchi-Fainaro R. K. Miller

45. Method and Device for Detecting Weak Optical Signals
Yosi Shacham-Diamand

46.Enhancement of Light Energy Conversion Efficiency by YBRID Nanoparticles Oriented Photosystem I Mono and Multilayer Based Optoelectronic Devices
Yossi Rosenwaks, H. Carmeli, L. Frolov, S. Richter, I. Carmeli

47. Optical Detection of Crystalline Regions in Self Assembled Organic Biomolecules
N. Amdursky, E. Gazit, G. Rosenman

48. Method of Growth of Homogeneous Crack-Free YBCO Layers
Guy Deutscher, Mishael Azoulay and Boaz Almog
Collaborations with Industrial Institutes

Chanoch Carmeli and Shachar Richter

Ehud Gazit
1. Cancer diagnostics, by nanotechnology based biosensor that profiles tissues acoustically. Amendis LTD.

Yael Hanein
2. Carbon nanotubes and MEMS, with RAFAEL.

Ilan Goldfarb
1. With US Air Force: Self-Organization of CoSi2 Nanostructures into Two-Dimensional Patterns. Supported by the US Air Force (Grant No# FA8655-07-1-3016 from the European Offices of the US Air Force Research and Development (EOARD)).

Rimona Margalit
1. In vitro studies on cancer cell lines, with Zetiq Technologies LTD.

Yossi Rosenwaks
1. Intel Research, Israel - Organic self-assembled monolayers for bioFET devices

Dr. Yoram Dagan:
1. The provskite based superconductor frromagnet transistor, Israel Science Foundation Bikura program, 2008-2011, 599,100 NIS (My part)

Judit Rishpon
1. A generic platform for milk sensors. Supported by the Nofar program (Ministry of Industry, Trade and Labor) in collaboration with S.A.E. Afikim and the Hebrew University Jerusalem.
2. Electrochemical immunosensor. supported by Quest International Miami USA
Collaborations with other Academic Institutes

**Reuven Boxman**


**Haim Diamant**


**Abraham Nitzan**

1. Prof. Mark Ratner, Dept. of Chemistry, Northwestern University, Evanston, IL

2. Prof. Leeor Kronik, Dept. of Materials and Interfaces, Weizmann Institute.

**Ehud Gazit**

1. Integration of peptide nanostructures in Alginate systems. Prof. Smadar Cohen Faculty of Health Sciences - Ben Gurion University of the Negev.


**Ilan Goldfarb**

1. With the Technion: Pushing the Limits of the “Bottom-Up” Approach: Self-Organized Growth of Silicide nanostructures on Si Surfaces. Supported by the Israel Science Foundation (ISF) Grant No. 410/08 - in collaboration with W.D. Kaplan (Technion) and E. Rabani (TAU).

2. With E.Rabani: Pushing the Limits of the “Bottom-Up” Approach: Self-Organized Growth of Silicide nanostructures on Si Surfaces. Supported by the Israel Science Foundation (ISF) Grant No. 410/08 - in collaboration with W.D. Kaplan (Technion) and E. Rabani (TAU).

**Guy Deutscher**

1. With P.G. de Gennes and with the group of Prof. Kapitulnik at Stanford.

**Alexander Kotlyar**

1. Prof. Dmitry Klinov, Shemyakin-Ovchinnikov Institute of Bioorganic Chemistry, Russian Academy of Sciences, Moscow, Russia.

2. Prof. Julio Gómez Herrero, Dept. of Condensed Matter, Free University of Madrid, Madrid Spain

3. Prof. Leonid Gurevich Aalborg University Institute of Physics and Nanotechnology Section for Biotechnology, Aalborg, Denmark.

4. Dr. Danny Porath, Dept. of Chemical Physics, The Hebrew University of Jerusalem, Jerusalem, Israel.

**Shachar Richter**

1. Electrical properties of DNA-Block Copolymer Nanoparticles. Mukhles Sowwa (El-Kuts University, Palestinian Authority, Andreas Herrmenn, Groningen University, Netherlands)

2. Molecular Capacitance, Hagai Cohen, Weizmann Institute of Science, Israel

3. Optoelectronic properties of Optoelectronic Properties of Hybrids made out of Carbon Nanotubes and the Photosystem I (Alexander W. Holleitner, Technische Universität München, Germany)

4. Dr. Mukhles Sowwan, Material Science Engineering Department, Al-Quds University, Abu dis.

**Yossi Lereah**

1. Group of Prof. Richard Kofman, Nice University (France)

2. Group of Prof. Hannes Lichte, Dresden University (Germany)

3. Dr. M. Pawlyta, from Poland (for 2 months)

**Ron Lifshitz**

1. Lab of Mordechai Segev, Physics, Technion.

2. Lab of Michael Roukes, Physics, Caltech.

3. Group of Michael C. Cross, Physics, Caltech.

**Michael Gozin**

1. Prof. Howard Weiner, Center for Neuroligic Diseases, Harvard Medical School, Boston, MA.

2. Dr. Eyal Mishani, Hebrew university, Jerusalem, Hadassah hospital, Dept. of Medical Biophysics & Nuclear Medicine
Yossi Rosenwaks
1. H. Haick, Technion – Self-assembled monolayers on Si.
2. North Western University, USA-Si Nanowires
4. Soreq research center - UHV-KPFM of Quantum dots

Ronit Satchi-Fainaro
1. Jindřich Kopeček, Department of Pharmaceutics and Pharmaceutical Chemistry, Center for Controlled Chemical Delivery, University of Utah, 20 S. 2030 E. Rm. 205B, Salt Lake City, Utah 84112-9452, USA.
2. Tatuuro Udagawa, Vascular Biology Program and Department of Surgery, Karp Family Research Laboratories, Children's Hospital Boston and Harvard Medical School, 1 Blackfan Circle, Boston, MA 02115, U.S.A.
3. María Jesús Vicent, Centro de Investigación Príncipe Felipe, Medicinal Chemistry Unit, Polymer Therapeutics Laboratory, Av. Autopista del Saler 16, E-46012 Valencia, Spain.
1. Rainer Haag, Organic and Macromolecular Chemistry, Department of Chemistry and Biochemistry, Freie University , Berlin, Germany
2. Felix Kratz, Tumor Biology Center, Breisacher Straße 117, 79106 Freiburg, Germany

Yosi Shacham-Diamand
1. The Smarthand project: Tyndall Institute, Ireland, Aalborg University, Denmark, ARTS Lab and CRIM Lab, Scuola Superiore Sant’Anna, Pisa, University Hospital, Malmo, Sweden, Lund University, OSSUR inc (Iceland)
2. The ReNaChip Project. UNEW (Newcastle University, UK), UPF (Spain), G.Tec (Austria), Lund University (Sweden).
3. DipChip: the University of Koblenz (Germany)

Itai Benhar
1. Antibody-based electronic switches. Collaboration with Uri Sivan and Yoram Reiter of the Technion

Dr. Yoram Dagan
1. Ultrafast optical spectroscopy of electron-doped cuprates, with Jure Demsar, Konstanz University.
2. Probing Local and Macroscopic orders in cuprates: with Richard L. Greene, University of Maryland.

Guy Deutscher
2. Polar Kerr effect… with the group of Aharon Kapitulnik, Stanford University.

Eran Rabani
1. Prof. Davud Reichman. Columbia, NY
2. Prof. Andrew Millis, Columbia, NY
3. Dr. Irene Burghadt, Ecole Normal Superior, Paris
4. Prof. Rossky, University of Texas, Austin
5. Prof. Uri Banin, Hebrew University
6. Prof. Roi Baer, Hebrew University
7. Prof. itamar Wilner, Hebrew University

Alexander Gerber
1. Magnetic semiconductors, with University of L’Aquilla, Italy

Gil Markovich
2. Prof. Sara Majetich, Carnegie-Mellon University, Pittsburgh, PA
3. Prof. Hennes Lichte, Dresden Technical University, Dresden, Germany
4. Dr. Tsachi Livneh, Nuclear Research Center, Beer-Sheva
5. Prof. Oded Shoseyov, Dr. Danny Porath, Hebrew University

Inna Slutsky
1. Quantum wires and dots (Ministry of Science, Ukraine-Israel) collaboration with Prof. I. V. Krive (Kharkov University).

Alexander Palevski
1. Paul Slesinger, Salk Institute, San Diego
2. Bernhard Bettler, Basel University, Switzerland
3. Gerd Multhaup, Free University, Berlin
4. Baruch Minke, Hebrew University
TAU Nano Related Faculty Scientific Groups

**Physics**

**Prof. David Andelman**
Polymeric nano-templates and nano-structures (theory)
andelman@post.tau.ac.il

**Prof. Eshel Ben-Jacob**
Nano Bio Electronics
eshel@tamar.tau.ac.il

**Dr. Yoram Dagan**
Superconductivity and ferro-magnetism in the nanoscale
yodagan@post.tau.ac.il

**Prof. Guy Deutscher**
Melting of nano-grains, superconductivity in nano-grain composites
guyde@post.tau.ac.il

**Prof. Alexander Gerber**
Giant magneto-resistance in nano-composites
gerber@post.tau.ac.il

**Prof. Ron Lifshitz**
Electro-mechanical properties of nanostructures (theory)
ronlif@post.tau.ac.il

**Prof. Alexander Palevski**
E-transport in low-dimensional semiconductor nanostructures
apalev@post.tau.ac.il

**Chemistry**

**Prof. Ori Cheshnovsky**
Nanoscale optics in STM junctions, Electronic properties of clusters
orich@chemsg1.tau.ac.il

**Prof. Haim Diamant**
Theory of Complex Fluids
hdiamant@tau.ac.il

**Dr. Michael Gozin**
Preparation, characterization and biomedical applications of fullerene/nanotube protein complexes; novel fullerene-derived amino acids and peptides (with Prof. A. Kotlyar)
cogozin@post.tau.ac.il

**Dr. Oded Hod**
Computational Nano-Materials Science: towards electronic, spintronic, and electro-mechanical devices at the nanoscale
odedhod@post.tau.ac.il

**Prof. Joseph Klafter**
Single molecule dynamics, nanomotors and nonfriction (theory)
klafter@post.tau.ac.il

**Prof. Gil Markovich**
Synthesis and physical studies of colloidal nanoparticles and their assemblies
gilmar@post.tau.ac.il

**Prof. Abraham Nitzan**
Electronic processes at molecular interfaces (theory)
nitzan@post.tau.ac.il

**Prof. Fernando Patolsky**
The synthesis and characterization of new nanoscale materials for the development of nanoelectronic, electro-optic and electro-magneto-optical devices and their applications in biology, chemistry and technology
fernando@post.tau.ac.il

**Prof. Emanuel Peled and Prof. Diana Goldnitsky**
Nano materials and thin films for electrochemical energy storage and conversion
peled@post.tau.ac.il

**Dr. Moshe Portnoy**
Nanoscale composite materials for catalysis and biomedicine
portnoy@post.tau.ac.il

**Prof. Eran Rabani**
Theory of nano-materials (theory)
rabani@post.tau.ac.il

**Dr. Shachar Richter**
Molecular electronics of self assembly layers
srichter@post.tau.ac.il

**Dr. Yael Roichman**
Optical assembly of new materials and devices
roichman@post.tau.ac.il

**Prof. Eran Rabani**
The physics and chemistry of singles molecule junctions
selzer@post.tau.ac.il

**Prof. Michael Urbakh**
Theoretical studies and modeling in fields of nanomechanics’ frictions at the nanoscale, single molecular spectroscopy and molecular motors
urbakh@post.tau.ac.il
TAU NANO RELATED FACULTY SCIENTIFIC GROUPS

**Engineering**

**Prof. A. Boag and B. Steinberg**  
Photonic crystals  
boag@eng.tau.ac.il

**Prof. Reuven Boxman, Prof. S. Goldsmith, Dr. Nahum Parkansky and Dr. Vladimir Zhitomirsky**  
Electrical discharge and plasma lab  
boxman@eng.tau.ac.il

**Dr. Noam Eliaz**  
Design, synthesis and characterization of new osteoconductive functionally graded hydroxyapatite coatings; biomaterials, electrochemistry, SPM  
neliaz@eng.tau.ac.il

**Prof. Eliezer Kit and Yoram Shapira**  
Interface between bio-molecules and nano-electronic structures and devices  
kit@eng.tau.ac.il

**Prof. Ilan Goldfarb**  
Growth of epitaxial nanostructures, STM  
ilang@eng.tau.ac.il

**Dr. Yael Hanein**  
Microfluidics for self-assembly, nanotubes-neurons interfaces  
hanein@post.tau.ac.il

**Prof. David Mendlovic**  
Silicon nano-photonic dynamic devices  
mend@eng.tau.ac.il

**Prof. Touvia Miloh**  
Nano-mechanics, fluid dynamics in nano-channels; elastic nano-fibers (theory)  
miloh@eng.tau.ac.il

**Prof. Menachem Nathan**  
Micro-batteries, Optical biosensors  
nathan@eng.tau.ac.il

**Prof. Gil Rosenman**  
Ferroelectric nanodomain polarization reversal and development of a new generation of nonlinear photonic devices  
gilr@eng.tau.ac.il

**Prof. Yossi Rosenwaks**  
Nano-probing, scanning probe microscopy  
yossir@eng.tau.ac.il

**Prof. Yosi Shacham-Diamand**  
Nano-chemical processes for microelectronics and integration of biological material on chip for acute toxicity detection  
yoshis@eng.tau.ac.il

**Prof. Shlomo Ruschin**  
Micro-electrooptics  
ruschin@eng.tau.ac.il

**Prof. Arie Ruzin**  
Solid state detectors and devices laboratory  
aruzin@eng.tau.ac.il

**Prof. Yoram Shapira**  
Tailoring of silicon surfaces by electrochemical grafting and deposition of biomolecules  
shapira@eng.tau.ac.il

**Dr. Jacob Scheuer**  
Integrated nano-photonics, slow light and polymer optics  
kobys@eng.tau.ac.il

**Prof. David Mendlovic**  
Silicon nano-photonic dynamic devices  
mend@eng.tau.ac.il

**Prof. Reuven Boxman, Prof. S. Goldsmith, Dr. Nahum Parkansky and Dr. Vladimir Zhitomirsky**  
Electrical discharge and plasma lab  
boxman@eng.tau.ac.il

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Interface between bio-molecules and nano-electronic structures and devices  
kit@eng.tau.ac.il

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ruschin@eng.tau.ac.il

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mend@eng.tau.ac.il

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miloh@eng.tau.ac.il

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nathan@eng.tau.ac.il

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gilr@eng.tau.ac.il

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yossir@eng.tau.ac.il

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Nano-chemical processes for microelectronics and integration of biological material on chip for acute toxicity detection  
yoshis@eng.tau.ac.il

**Prof. Shlomo Ruschin**  
Micro-electrooptics  
ruschin@eng.tau.ac.il

**Prof. Arie Ruzin**  
Solid state detectors and devices laboratory  
aruzin@eng.tau.ac.il

**Prof. Yoram Shapira**  
Tailoring of silicon surfaces by electrochemical grafting and deposition of biomolecules  
shapira@eng.tau.ac.il

**Dr. Jacob Scheuer**  
Integrated nano-photonics, slow light and polymer optics  
kobys@eng.tau.ac.il

**Life Sciences**

**Prof. Ari Barzilai**  
The molecular mechanism of optic nerve degeneration and regeneration  
arib@tauex.tau.ac.il

**Prof. Itai Benhar**  
Targeted drug-carrying phage nanoparticles  
benhar@post.tau.ac.il

**Prof. Chanoch Carmeli**  
Application of the photosynthetic reaction center proteins, PS I in the fabrication of novel nanobio-photovoltaic devices  
carmeli@post.tau.ac.il

**Prof. Amihay Freeman**  
Biotemplating of stabilized protein crystals; directed metallization of biologically active proteins and cells  
amihayf@post.tau.ac.il

**Prof. Ehud Gazit**  
Self-assembly of short aromatic peptides: from amyloid disease to nanotechnology  
ehudg@post.tau.ac.il

**Prof. Yoav Henis**  
Nano-scale lipid domains and their role in Ras signaling  
yovah@tauex.tau.ac.il

**Prof. Alexander Kotlyar**  
DNA-based organic nano wires  
s2shak@post.tau.ac.il

**Prof. Rimona Margalit**  
Drug delivery by nano-particles based on biomaterials: biophysical properties, cell-particle interactions and therapeutic responses  
rimona@post.tau.ac.il
TAU NANO RELATED FACULTY SCIENTIFIC GROUPS

Dr. Dan Peer
Selective targeting and reprogramming of leukocytes using fully degradable nanomedicines • peer@post.tau.ac.il

Prof. Judith Rishpon
Application of nano technologies in electrochemical biosensors • judithri@tauex.tau.ac.il

Mathematics
Prof. Zeev Schuss
Ionic permeation in protein channels of biological membranes and applications to models of neurons and cardiac myocytes • schuss@post.tau.ac.il

Medicine
Prof. Dafna Benayahu
Nano manipulation of stem cells differentiation to become biomedical devices • dafnab@post.tau.ac.il

Prof. Rafi Korenstein
Electrical enhancement of drug nanocarrier, nanoscale cell membrane dynamics • korens@post.tau.ac.il

Dr. Ronit Satchi-Fainaro
Targeting tumor vasculature with polymer conjugates of angiogenesis inhibitors • ronitsf@post.tau.ac.il

Dr. Ella Sklan
Interactions of positive strand RNA viruses with the host cell • sklan@post.tau.ac.il

Dr. Inna Slutsky
Information processing: From nano-scale single synapse to memory function • islutsky@post.tau.ac.il

Dr. Ilan Tsarfaty
Nanoparticles based Met-HGF/SF molecular imaging • ilants@post.tau.ac.il
Head of the Center for Nanoscience and Nanotechnology

Prof. Ori Cheshnovsky

The scientific committee of the Center for Nanoscience and Nanotechnology

Prof. Guy Deutscher, Chairman of the scientific and managing committee
Prof. Ori Cheshnovsky, Head of the Center for Nanoscience and Nanotechnology
Prof. Ilan Goldfarb, Faculty of Engineering
Dr. Yael Hanein, Faculty of Engineering, representative – core researchers
Prof. Rimona Margalit, Faculty of Life Sciences
Prof. Gil Markovich, School of Chemistry and Astronomy
Prof. Alexander Palevski, School of Physics
Dr. Dan Peer, Faculty of Life Sciences
Prof. Yossi Rosenwaks, Faculty of Engineering
Dr. Inna Slutsky, Faculty of Medicine
Dr. Moshe Evenor, Managing Director
## Administrative and Technical staff

<table>
<thead>
<tr>
<th>Name</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dr. Moshe Evenor</td>
<td>Administrative manager</td>
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<tr>
<td>Lauren Itzhak</td>
<td>Secretary</td>
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<tr>
<td>Dr. Zahava Barkay</td>
<td>ESEM lab director</td>
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<tr>
<td>Dr. Yossi Lereah</td>
<td>HRTEM researcher and lab director</td>
</tr>
<tr>
<td>Dr. Alexander Tsukernik</td>
<td>Electronic microscope and E-Beam lithography lab manager</td>
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<tr>
<td>Gregory Avrushchenko</td>
<td>Nano Center Site Engineer</td>
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<tr>
<td>Moshe Eliyahu</td>
<td>AFM Laboratory</td>
</tr>
<tr>
<td>Assaf Hazzan</td>
<td>Clean Rooms Engineer (Nano center)</td>
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</tbody>
</table>

## TAU micro and nano central characterization & fabrication facility - personnel

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
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<tbody>
<tr>
<td><strong>Directors</strong></td>
<td></td>
</tr>
<tr>
<td>Prof. Ori Cheshnovsky</td>
<td>Academic co-director</td>
</tr>
<tr>
<td>Dr. Yael Hanein</td>
<td>Academic co-director</td>
</tr>
<tr>
<td><strong>Administration</strong></td>
<td></td>
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<tr>
<td>Inna Veksler</td>
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<tr>
<td><strong>Processing</strong></td>
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<tr>
<td>Mark Oksman</td>
<td>Chief Engineer</td>
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<tr>
<td>Maurice Saidian</td>
<td>Equipment Engineer</td>
</tr>
<tr>
<td>Assaf Hazzan</td>
<td>Equipment Engineer</td>
</tr>
<tr>
<td>Alexander Gurevitch</td>
<td>Process Engineer</td>
</tr>
<tr>
<td>David Shreiber</td>
<td>Training (student)</td>
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<tr>
<td>Elad Koren</td>
<td>Bonder (Student)</td>
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<tr>
<td><strong>AFMs</strong></td>
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<tr>
<td>Noam Sidelman-Mor</td>
<td>Atomic force microscopy</td>
</tr>
<tr>
<td><strong>SEMs</strong></td>
<td></td>
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<tr>
<td>Dr. Alexander Tsukernik</td>
<td>e-beam microscopy and lithography</td>
</tr>
<tr>
<td>Denis Glozman, Netta Hendler</td>
<td>Training (Students)</td>
</tr>
<tr>
<td><strong>ESEM</strong></td>
<td></td>
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<tr>
<td>Dr. Zahava Barkay</td>
<td>ESEM</td>
</tr>
<tr>
<td><strong>Glove boxes</strong></td>
<td></td>
</tr>
<tr>
<td>Gregory Avrushchenko</td>
<td>Lab Engineer</td>
</tr>
</tbody>
</table>