TEL AVIV UNIVERSITY

NANONEWS

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Supersensitive Detection of Explosives by "Nanonose" Arrays

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In the last decade there has been a great increase in the development of trace and ultra-trace explosive detection, mainly due to the globalization of terrorist acts, and the reclamation of contaminated land previously used for military purposes. In this regard, detection methods for traces of explosives continue to be plagued by their low volatility and thus, the analytical problem remains challenging[1-6]. One of the most commonly-used high explosives over the last 100 years is 2,4,6-trinitrotoluene (TNT), which poses not only a dire security threat, but also great environmental concern due to soil and water contamination. Thus, TNT is a suitable target analyte for chemical-sensing devices. Analytical procedures in use today for the trace detection of explosives typically involve collecting vapor samples and analyzing them with a sensitive method. Several methodologies have been reported for detecting TNT and other explosives. Although some reported methods are very sensitive and selective, most are rather, expensive, time-consuming and require bulky equipment, tedious sample preparation and an expert operator. Furthermore, these systems cannot be miniaturized and automated or cannot perform high-throughput analysis.

A successful chemical sensor for TNT, and any other explosives, must: (1) be extremely sensitive given that the vapor pressure of TNT at 25°C is 5.8×10^{-6} Torr (<10 ppb), and even lower for other commonly used explosives, such as RDX and HMX, with vapor pressures in the ppt and ppq levels, respectively, (2) be highly selective, eliminating both false positives and false negatives, (3) be robust and not prone to drift, (4) have the ability to be easily miniaturized for field application and (5) most important, be able to perform real-time high-throughput analysis based on arrays of multiple sensing elements.

Nanowire-based field-effect transistors (NW-FETs) are powerful potential new sensors for the detection of chemical and biological species.[7-12] Recently, extensive work has been carried out with the use of nanowire electrical devices for the simultaneous multiplexed detection of multiple biomolecular species of medical-diagnostic relevance, such as DNA and proteins. For NW sensors operated as FETs, the sensing

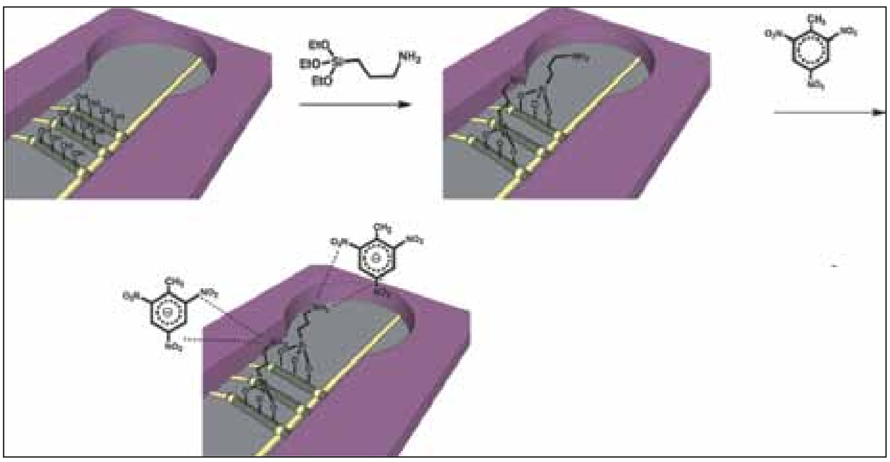

Figure 1.

a. Schematic representation of TNT molecules sensing by the sensor chip device.
b. Normalized conductance-versus-time of an APTES functionalized p-type SiNW FET sensor at (V_g=0) following the alternate delivery of TNT solutions of different concentrations and a reference solution. (a) 500 fM, (b) 5 pM, (c) 5 nM, (d) 75 nM, (e) 100 nM, (f) 500 nM, (g) 5 mM. Inset: Magnification of a single TNT binding/washing sensing event. Blue box denotes the time to reach sensing plateau.

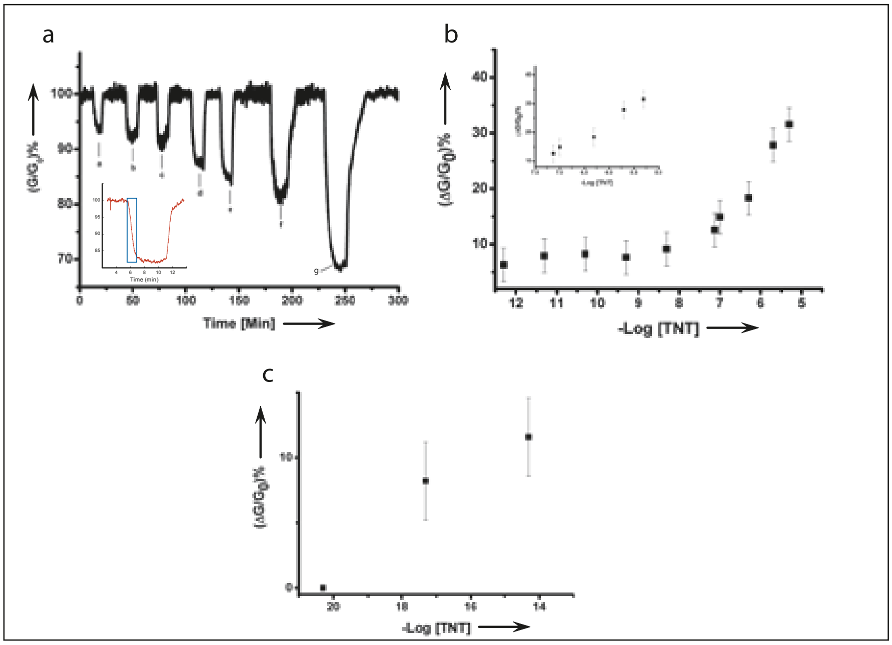

Figure 2.

a. Relative percent conductance change (DG/G_0) versus TNT concentration (drawn on a logarithmic scale).
b. Relative percent conductance change (DG/G_0) versus TNT concentration for an exceptionally sensitive device.

mechanism is the field-gating effect of charged molecules on the carrier conduction inside the NW.In our labs at TAU, we have demonstrated the supersensitive, rapid, label-free and real-time detection of TNT with the use of large-scale arrays of SiNW-FET devices, chemically-modified with a monolayer of an amine-functionalized silane derivative, namely 3-aminopropyltriethoxysilane (APTES), Figure 1a. TNT molecules can strongly bind to the surface of nanosensors through an acid-base pairing interaction between TNT molecules and amino ligands on the sensor surface. The exceptional performance of the SiNW devices enables the detection of TNT with unprecedented sensitivities reaching sub-femto (10^{-15}) molar concentrations (10^{-6} ppt).

To assess the efficacy of our system for the sensing of TNT, aqueous solutions (DI water containing 0.1% DMSO) spiked with TNT at concentrations ranging from 500 fM to 5 µM were delivered to the sensor chip device through a built-in-chip fluid-delivery system. Examination of the data, (Figure 1b), reveals that the conductance of the nanowires is extremely sensitive to the presence of TNT over the whole concentration range, and displays a well-defined increase and subsequent return to baseline when TNT solution and reference washing solution (DI water containing 0.1% DMSO), respectively, are alternately delivered through the fluid-delivery system to the devices. A plot of these data shows (Figures 2a and 2b) that the change in conductance is directly proportional to the TNT concentration for values from ~50 µM down to 5 nM. The nanosensors can unmistakably detect TNT down to concentrations well below the femtomolar level (~0.5 femtomolar). Even further, the most sensitive devices can sense TNT down to the 50-100 attomolar range, (Figure 2c). In addition, sensing can be performed rapidly - in less than a minute - without the need for pre-concentration steps. The change in conductance begins immediately upon exposure of the nanowire device to the TNT solution, and stabilizes at a new value over a period of a few minutes.

When considering a real-time field sensor, the reversibility of the sensor is a key factor. When the reference washing solution containing no TNT is introduced into the system, after TNT had been flowing through the sensors, the device again responds very rapidly, and the conductance returns to its baseline value. Another interesting and important observation is that we have performed ~100 repeated TNT injection/wash cycles with the same nanowire device for over more than a week, and found remarkable sensing stability and reproducibility.

In order to improve the detection limit of a sensor it is not only necessary to have a high gain but also to reduce the noise level, and so provide a high signal-to-noise ratio, thus also preventing the high number of false-positive and false-negative incidents, intrinsic to current sensing technologies. One strategy to achieve this goal is by employing a large number of identical sensors sensing the same analyte molecule simultaneously to enhance the signal-to-noise level. Our sensor chip is designed to contain close to 200 devices that can potentially perform the simultaneous detection of TNT. To demonstrate this, we performed the detection of TNT simultaneously by three nanowire-devices.

In addition, we tested our nanonose arrays for their capability to sense TNT directly from air samples. The gas-phase detection of TNT vapor was conducted with the same detection set-up, but using either a nitrogen-gas or compressed dry-air stream as the carrier of TNT vapor to the sensing chip. Clearly, the presence of TNT

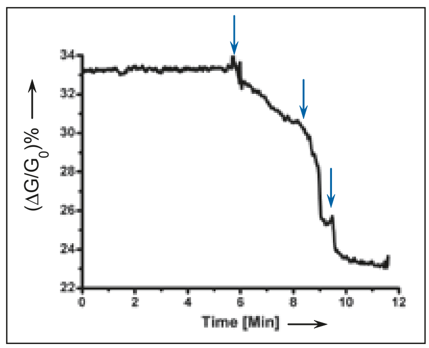

Figure 3.
Relative percent conductance change (DG/G_0) versus time for an APTES functionalized p-type SiNW FET sensor after short pulses of TNT vapors in carrier air samples (arrows denote the time when the vapor pulse was performed).

vapors is easily and rapidly detected by the nanosensor arrays, (Figure 3). This shows that the nanosensors are extremely sensitive to the presence of TNT in air and that long sampling and most importantly, that pre-concentration steps are not required in our platform. The sensing of TNT in air could be performed for tens of cycles at low concentrations of TNT (between ppb and ppt concentrations), with a sensitivity limit similar to that measured in solution-sensing experiments. If required, the sensor surface can be readily reactivated by a short washing step in water/0.1% DMSO solutions. This removes any TNT molecules bound to the sensing surface through charge-transfer complexes, and brings it back to its initial baseline state.

The possibility of sensing TNT vapors directly and rapidly from air-collected samples without pre-concentration, and the effective complete regeneration of sensing elements, are of fundamental importance in the future deployment of our platform in the real-world detection of explosives.

In conclusion, these studies have demonstrated a rapid, label-free, real-time super-sensitive detection with high selectivity for TNT with the use of large arrays of chemically-modified SiNW-FETs with a detection limit reaching the attomolar concentration range. Moreover, our results showed that the developed sensors could distinguish TNT from other related compounds, with or without nitro groups, and exhibit a clear concentration-dependent conductance response for TNT. This approach represents the first generation of selective and super-sensitive electronic noses intended for the detection of TNT and other explosive-chemical analytes. We hope in the future to expand the research towards a universal platform for the label-free simultaneous detection of a larger spectrum of explosive chemical agents.

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On February 9th the nanocenter researchers and students went north to Maalot to Hacienda Forest View for the 6th annual workshop of the Center for Nanoscience and Nanotechnology. While consuming 7000 calories of food and deserts we heard 19 talks looked at many posters and had many opportunities to meet and discuss new ideas and scientific collaborations.

We had a large variety of talks from the various disciplines comprising the nanocenter: starting from quantum effect in nanomechanical devices going through nonlinear photonic crystals and analyses of mast cell activation. This year we made a special effort to bring student presentations to the front. The scientific committee chose 4 outstanding abstracts for an oral presentation. As usual, the poster flash session was very lively and poster presenters had about 5 minutes to give a taste of their work. For those of you who have forgotten some of the details in these many presentations there is a Video recording of the entire meeting.

We should also note the many prizes awarded: two poster flash presenters and three poster presents received a prize for their presentation. Two lecturers received an IPod-nano for their "interdisciplinary" presentation aiming to explain complex scientific problems to scientists from other disciplines.

Finally, we should mention the pleasant and collaborative environment during the meeting which reflects the spirit of the nanocenter as a place for sharing not only equipment and facilities but also ideas and knowledge.

New Tools and software

Cary 5000 UV-VIS-IR spectrophotometer

Cary 5000 UV-VIS-IR spectrophotometer with Diffuse Reflectance Accessories is top of the line high resolution instrument. It can measure samples with both very high and very low absorbance. The diffuse reflectance accessory enable absorption and reflection determination of highly scattering samples such as nano particles, nanotubs, surfaces and biological organelles. It can resolve the absorption of monolayer of organic molecules, charomophors, peptides, DNA and proteins attached to nanoparticles or to transparent and nontransparent solid surfaces. Attachment of molecules to nano structures is a central team in nanoscience research. The study of the spectrum of the attached molecules is essential for determination the extant of attachment and the nature of interactions between the molecules and the solid state.

Specification: Wavelength Range 175-900 175-3300;Photometric Range (Abs) 8

Accessory: DRA-2500, Intrnally mounted Diffuse Reflectance Accessory for Cary 5000. Has its own PMT (UV-Vis range) and peltier cooled Lead; Sulfide PbS detector (NIR range); Spectral Range 200-2500 nm

Fixed beam Moving Stage (FBMS) module in Raith lithography systems

The FBMS lithography module comprises design, control and exposure of structures within a GDSII data base in a fixed beam-moving-stage mode. The FBMS exposure mode yields excellent precision and flexibility in fabricating thin but extended lines or paths (limited only by the stage travel range) **with no stitch field boundaries**. This is an ideal replacement for the standard step and repeat strategy for long lines production, in which stitching error of several tens of nanometers is always present. Typical applications of the FBMS mode are fabrication of integrated optics structures like waveguides or x-ray optics.

Exposures can be realized with a **true stationary beam** or with a **programmable high speed beam shape** continuously formed by the pattern generator during controlled stage movement. The latter operation allows fabrication of well defined line widths without having the need to rely on a defocused beam. The patterns to be exposed are fully integrated into an extended GDSII database and editor. Standard beam scanning and path control exposure sequences can be mixed and executed directly from a single GDSII file. The FBMS editing functionality allows to define arbitrary shaped lines of any geometry and to prepare them for direct exposure in FBMS control mode.

In FBMS exposure mode the stage motion is controlled via an intelligent stage electronics based on a high performance digital signal processing (DSP) architecture. The stage controller adds fast beam tracking in fixed beam moving stage mode to the closed loop piezo fine shift operation in the standard Raith stage control.

Raith ionLiNE

The Raith *ionLiNE* is an advanced focused ion-beam nanofabrication instrument designed and characterized to meet lithography tool standards. The unique components are the patented NanoFIB column, the ELPHY pattern generator, the laser interferometer stage, and a complete lithography software package, all integrated into one system to enable advanced ion-beam patterning. The ion-beam source and column produce the beam stability required for automated advanced lithography. With a small beam diameter and nominal beam tails, the focused ion-beam offers high lateral selectivity, enabling fabricated feature sizes of 10 nanometers and below. Exposures are made in a variety of scan modes using a high speed 16-bit pattern generator. The pattern generator technology enables nanosecond ion dose control and 3D grey level patterning. For applications covering areas larger than a single exposure field, the laser interferometer stage provides positioning resolution of 1 nm. With these unique features, the *ionLiNE* delivers critical lithography specifications, such as stitching and overlay accuracies. The lithography software permits the generation or import of complex patterns in the widely accepted GDSII data format, job automation for overnight patterning without user interaction, automated dose control and metrology. Fixed Beam Moving Stage (FBMS), a zero stitching error writing mode for the seamless exposure of extended structures, completes the advanced patterning of the *ionLiNE*. Additional options, such as a gas-injection system and nanomanipulators and 3D tilt rotation module, are added to allow unique nanofabrication and nanoengineering capabilities.

Research news

Controlling and manipulating electron spins may add an additional degree of freedom in future electronics, doing so by applying an electric field is a major challenge for spin-electronics (spintronics). This is because it is much easier and more practical than applying magnetic field. Such electric field control is possible through the Rashba spin-orbit coupling resulting in an effective magnetic field: $\mathbf{B}_{eff} \propto \mathbf{E} \times \mathbf{k}$. Where E is the electric field and k is the electron momentum.

In our lab we showed that this spin-orbit coupling can be tuned in the two dimensional electron gas formed between the two insulating perovskites $SrTiO_3$ and $LaAlO_3$.

The conductivity at this interface surprisingly appears for $LaAlO_3$ film thicker than four unit cells. The interfacial conducting layer is also superconducting with a critical temperature depending on gate voltage, reaching a maximum of 350mK.

We reported the effect of Rashba type spin-orbit coupling on magneto-transport when a gate voltage (and hence electric field) was applied perpendicular to the interface. From our results we were able to extract the spin orbit coupling energy.

M. Ben Shalom, M. Sachs, D. Rakhmilevitch, A. Palevski, Y. Dagan
Tuning spin-orbit coupling and superconductivity at the $SrTiO_3/LaAlO_3$ interface: a magneto-transport study. *Phys. Rev. Lett*. (In press)

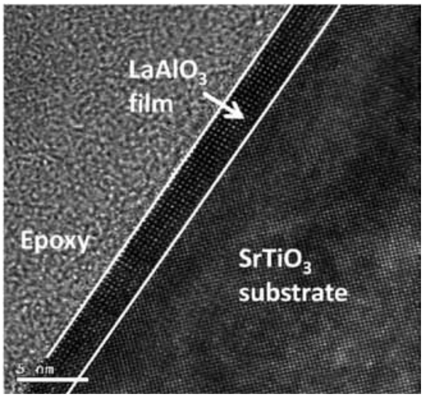


Figure 2: High resolution transmission electron microscopy image of LaAlO3\SrTiO3 interface. The lines outline the LaAlO3 film boundaries. The number of LaAlO3 layers matches the number of RHEED oscillations during deposition.

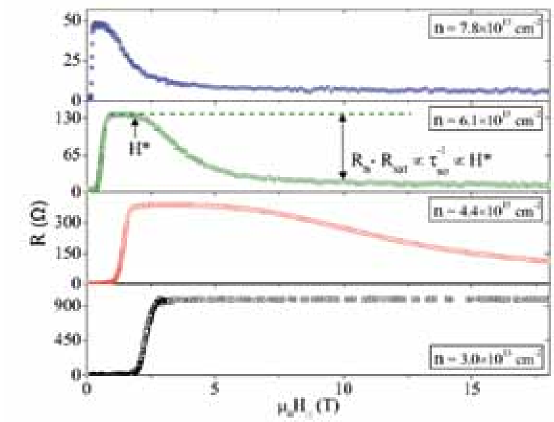


Figure 1: Sheet resistance as a function of magnetic field applied parallel to the interface for the various carrier densities controlled by the gate voltage at 20mK. H* represents the field whose Zeeman energy is comparable to the spin-orbit coupling.

Physical Properties of Peptide Nanostructures

Nadav Amdursky

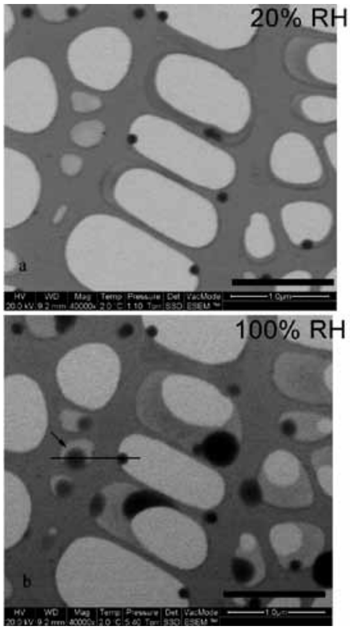
In our studies we report for the first time in the bio-organic world on the direct observation of quantum confined nanocrystalline structure at various peptide nanostructures (PNS). These highly ordered building blocks of the structures have been observed from optical studies where pronounced quantum confinement (QC) and photoluminescence, which results in an intense blue emission, have been revealed. We found a step-like optical absorption behavior, which is a distinguished feature of 2D-QC, and a spike-like behavior, which is a feature of 0D-QC. By calculations we have estimated the dimension of those crystalline regions to be at the order of only ~1 nm, a size that is most difficult to achieve at the inorganic world using common deposition techniques. These data directly indicates on the presence of fine crystalline structure at the PNS and allows relating these PNS to self-assembly ceramic-like nanostructural bio-inspired material. By following the formation of the exciton we could follow the self-assembly process of the structures. The nanocrystalline structure, in addition to the $P6_1$ crystal symmetry of the peptide nanotubes, promoted us to assume the existence of piezoelectric properties and second harmonic generation (SHG) in these structures. From our piezoelectric measurements we indeed found a strong longitudinal and shear piezoelectric response where d_{15} shear piezoelectric coefficient has reached 70-100 pm/V. We have also found strong SHG from the peptide nanotubes. In addition to the strong SHG, a pronounced threshold for the two photon luminescence was observed, this indicate on the possibility of the nanotubes to serve as a lasing material.

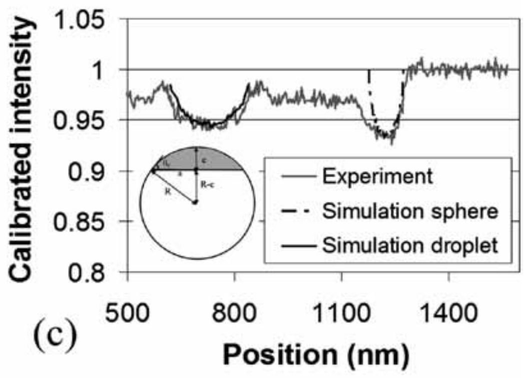
The new physical findings, which were previously found mainly in inorganic materials, may pave the way for the incorporation of bio-inspired PNS toward green devices, such as: LEDs, lasers and actuators.

Wettability study using transmitted electrons in environmental scanning electron microscope

Zahava Barkay

The investigation of wetting properties of surfaces at nano-scale spatial resolution and high temporal resolution is an emerging research field. The current research is pioneering in studying droplets directly on fluid self-supported interface at nano-scale spatial resolution and high temporal resolution. A method was developped[1], which is based on measuring transmitted electrons through nanodroplets using wet scanning transmission electron microscope (wet-STEM) detector in environmental scanning electron microscope. The quantitative information of the nanodroplet shape and contact angle is obtained by fitting Monte Carlo (MC) simulation results for transmitted electrons through spherical cap geometry with the experimental wet-STEM results. The MC simulation program was developed for specific particle geometries and the characterization was demonstrated for initial stages of water droplet condensation over a non-homogeneous holey carbon grid.





Polystyrene water diluted spheres on carbon grid (scale bar is 1μm): (a) at 2 °C and 1.1 torr, (b) nanodroplet condensation at 2 °C and 5.4 torr, (c) calibrated profile along the center of the nanodroplet and the calibration nanoparticle together with the MC simulations (inset-schematic of spherical cap droplet mode).

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Basal GABA regulates GABA(B)R conformation and release probability at single hippocampal synapses

Laviv, T., Riven, I., Dolev, I., Vertkin, I., Balana, B., Slesinger, P. A., and Slutsky, I.

This work combines high-resolution optical and spectroscopic tools to determine structure-function relationship at the level of individual neuronal connections (synapses). The dynamics of protein-protein interactions was measured by fluorescence resonance energy transfer (FRET) and correlated to activity of synaptic vesicle release at single synapses in live neurons. Utilizing these integrated system, we revealed a mechanism that determines heterogeneity of basal activity at the single-synapse level in neuronal networks. The research will be published in **Neuron** (2010)

Natural-Synthetic Malleable Composite Hydrogel Hibrid for Tissue Engineering

Moran Aviv, Ludmila Buzhansky, Shmuel Einav, Zvi Nevo and Ehud Gazit

Development of malleable polymeric nanofibers constracts is of a great scientific and technological interest due to their wide-range applications in biomedicine and biotechnology. Particularly, composite nanofibers derived from natural and synthetic polymers, combining the favorable biological properties of the natural polymer and the mechanical strength of the synthetic polymer, represents a major advantageous advancement in tissue engineering and regenerative medicine. Our work is focus on the development and characterization of an innovative natural-synthetic polymeric nanofiber hydrogel hybrid comprised of hyaluronic acid (HA) and the self-assembled peptide, FmocFF (fluorenylmethoxycarbonyl-diphenylalanine). HA, a biodegradable, nonimmunogenic, and biocompatible natural polymer, which represent remarkable viscoelastic properties, is an attractive biomaterial for cells in tissue engineering. FmocFF is a short peptide (FF-diphenylalnine) with a protected group (FmocFF), which can self assembled into nanotubes and form hydrogels as macrostructure. The mixing between these two components, without using any chemical crosslinkers agents, results in hydrogels that are characterized both by a remarkable rigidity in comparison to HA, and biocompatibility in comparison to FmocFF alone. These innovative hybrids present a unique, rainbow of agents (in respect to the ratios of the basic two components), remarkable rheological, viscoelastic, swelling and biodegradability properties that has multifunctional properties supporting growth of all kinds of cultures. The design combines the technological advances in biocompatible polymers and nanofibrous matrices with significantly improved mechanical and biological properties.

Ultra-sensitive biosensor for environmental monitoring, combining electrochemistry and surface modification using aromatic dipeptide nanostructure and carbon nanotubes

Lihi Adler-Abramovich, Michal Badihi-Mossberg, Judith Rishpon, Ehud Gazit

We aim to increase the sensitivity of an environmental sensor, for the detection of phenol by combining both CNT and peptide nanotubes on the same electrode. An amperometric enzyme-based biosensor was designed by decorating standard electrodes with both CNT and peptide nanotubes, consequently improving the sensor sensitivity 13-times, in comparison to the absence of the nanostructures. The work was extended and sensors based on various nanostructures, all member of the aromatic dipeptide nanostructures family were designed. Cyclic voltammetric and time-based amperometric techniques demonstrated that the integration of dinaphthylalanine peptide nanotubes or Boc-Phe-Phe-OH peptide nanospheres into biosensor electrodes, increased sensitivity of the electrochemical measurements. Notably, electrode coated with nanoforest, vertically aligned peptide nanotubes, showed the highest sensitive phenol detection, 17-times than a bare electrode

The research was published recently in the *Small* journal

Honors and Prizes

Ehud Segal, a graduate student in the school of medicine won the Barenholtz Prize for Applied Research. He will receive the prize at a ceremony next Wednesday 9.6.2010 at the Hebrew University.

Iftach Dolev, a PhD student in Dr. Slutsky laboratory, has been awarded by Azrieli Fellowship for excellence in graduate study. Iftach explores endogenous mechanisms that regulate initiation of Alzheimer's disease.

Nadav Amdursky, a PhD student in Prof. Ehud Gazit laboratory has won the award of the Optical Society of America student chapter and the Charles Clore fellowship

New faces in the Center

Dr. Iftach Nachman

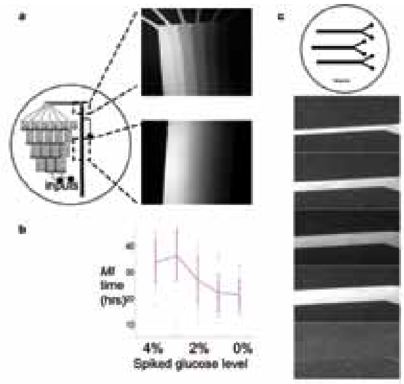
Our goal is to understand how cells within a population reach developmental decisions at the phenotypic and mechanistic level. How do cells "decide" to change their state? Why do similar cells respond differently to the same signal? What properties of the cell affect its decision? Our lab will study these fundamental questions in two model systems using methods from live cell fluorescent imaging, **microfluidics**, statistical and computational analysis.

Propagation of information through signaling and transcriptional pathways

Cell populations in the nature face different cues from the environment that change in different frequencies. For example, a yeast colony in the vineyard senses different levels of heat, humidity, osmolarity and nutrient levels changing at different rates. Effective response to these fluctuating cues raises several challenges. Can the cells distinguish between a fleeting cue and a consistent change? Can they filter out the former to avoid mistaken decisions? How do their signaling and transcriptional networks handle these complex fluctuations? We will study responses to signal fluctuations in the yeast meiosis process using live cell microscopy and **custom-designed microfluidic devices** capable of generating spatial and temporal signal gradients.

Differentiation dynamics in size-controlled embryoid bodies

In-vitro differentiation of embryonic stem cells into defined cell types is a field of immense importance for both regenerative medicine and for basic understanding of development. Embryoid bodies (EB's), three dimensional aggregates of differentiating embryonic stem cells, have been the method of choice for in-vitro differentiation into many cell types, including motor neurons, hepatocytes and cardiomyocytes. I suggest a **microfluidic**-based system for controlled EB formation, for generation and imaging of both uniform and variable size and shape EB's. We will study correlates of specific cell fate differentiation and cell movement patterns in EB's by imaging large numbers of such systems, in conjunction with protein reporter and lineage tracing fluorescent constructs. The project will enhance our basic understanding of cell movement and rules of differentiation during development, and can lead to improved protocols of in-vitro differentiation.



Signal perturbations with spatial or temporal gradients in microfuidic devices. ***a***. A microfluidic flow cell capable of generating a stable concentration gradient, shown in the insets on the right. By combining this device with time varying inputs, we create a signal pulse with a spatial gradient. ***b***. Using the setup above, we measured the meiosis decision time as a function of the spike glucose level. The results show an increase in decision time and variability which depend on the fluctuation strength over a limited range. ***c***. By gradually changing the flow pressures in the two inputs of a Y-shaped flow channel, we obtain different spike durations along the width of the channel. Multiple Y channels allow measurement of different conditions in parallel.

Iftach Nachman

Dr. Iftach Nachman has joined the Faculty of Life Sciences and is a new member in the Safra program and an Alon fellow.

He completed a BSc in physics at TAU, a PhD in computational biology at the Hebrew University, and combined experimental and computational work during his postdoc at Harvard University and the Broad Institute.

Dr. Avigdor Eldar

My name is Avigdor Eldar and I recently returned from a post-doc at Caltech to establish an independent lab at the faculty of life science, the department of molecular microbiology and biotechnology. My original undergraduate background is in mathematics and physics, which I studied in the Hebrew U. within the framework of the army's Talpiot project. My master degree was done here, in Tel Aviv University Physics department. Under the supervision of Amir Levinson, I theoretically studied properties of active galactic nuclei. I then decided to shift my focus to Biology and did my PhD at the Weizmann Institute. Under the supervision of Naama Barkai, I theoretically and experimentally studied mechanisms that shape the patterns of developing embryos. During my post-doc at Caltech I worked with Michael Elowitz on subjects concerning the stochastic nature of biological processes and their implication to microbial development and evolution.

In my new lab I will study different aspects of pattern formation and symmetry breaking on different scales of biological organization, using bacteria as the main model organism. I will combine modeling of regulatory and mechanical systems in bacteria with a diverse spectrum of experimental technologies, focusing on molecular biology and advanced microscopy. My interaction with the Nano center is based on my interest in developing and using super-resolution techniques and optogenetic techniques to control molecule assembly as submicron resolution. I hope this will also help me reach students from physics and engineering who are interested in understanding systems' level complexity of live organisms and want to combine experimental and theoretical work in this field. Here are three examples for questions I plan to study on three different length-scales of biological organization:

Pattern formation, differentiation and signaling in microbial communities. Microbial communities exhibit a reach spectrum of cell types and form patterns over scales ranging from tens of microns to centimeters. These patterns depend on environmental conditions and a range of signals secreted by cells to communicate with each other. I will use a novel a technology that allows control of gene activity by light to study the response of the community to imposed patterns of signals and decipher 'communication protocols' that guide community organization.

Cell division site selection and symmetry breaking. Bacterial cells typically multiply by accurate medial division. However, under specific conditions, cells will divert their selected division site to an asymmetrical site. Using genetics approaches and microscopy, I will study the mechanisms underlying symmetry breaking in bacterial cells from the regulatory and mechanistic perspective. Specifically, light regulation techniques allow the localization of proteins to the membrane within the cell with a diffraction limit resolution. This will enable us to study division site selection by controlling the division site location and studying its assembly dynamics at various positions.

Super resolution analysis of cross-septal organization. The formation of asymmetric division is characterized by localization of different proteins to the two sides of the division septum and formation of specific patterns of proteins localization, based on cross-septal interactions. The typical scale of these pattern is ~50-100nm, which fits nicely with the current capabilities of super resolution techniques. I will study the asymmetry of protein assembly, the nature of complexes formed within a compartment and the type of cross-septal interactions.