Abstracts - Nanomaterials session

Type	Name	Affiliation	Gender	Position
Keynote	Uri Banin	HUJI	Male	Professor

Coupled Colloidal Quantum Dot Molecules

Uri Banin

Institute of Chemistry and the Center for Nanoscience and Nanotechnology,
The Hebrew University of Jerusalem, Jerusalem 91904, Israel.
Email: uri.banin@mail.huji.ac.il
https://openscholar.huji.ac.il/baningroup/home

Colloidal semiconductor Quantum Dots (CQDs) containing hundreds to thousands of atoms have reached an exquisite level of control, alongside gaining fundamental understanding of their size, composition and surface-controlled properties, leading to their technological applications in displays and in bioimaging [1]. Inspired by molecular chemistry, deeming CQDs as artificial atom building blocks, how plentiful would be the selection of composition, properties and functionalities of the analogous artificial molecules? Herein we introduce the utilization of CQDs as basic elements in nanocrystal chemistry for construction of coupled colloidal nanocrystals molecules. Focusing on the simplest form of homodimer quantum dots (QDs), analogous to homonuclear diatomic molecules, we introduce a facile and powerful synthesis strategy with precise control over the composition and size of the barrier in between the artificial atoms to allow for tuning the electronic coupling characteristics and their optical properties. This sets the stage for nanocrystals chemistry to yield a diverse selection of coupled CQD molecules utilizing the rich collection of artificial atom core/shell CQD building blocks. Such CQD molecules are of relevance for numerous applications including in displays, photodetection, biological tagging, electric field sensing and quantum technologies [2,3].

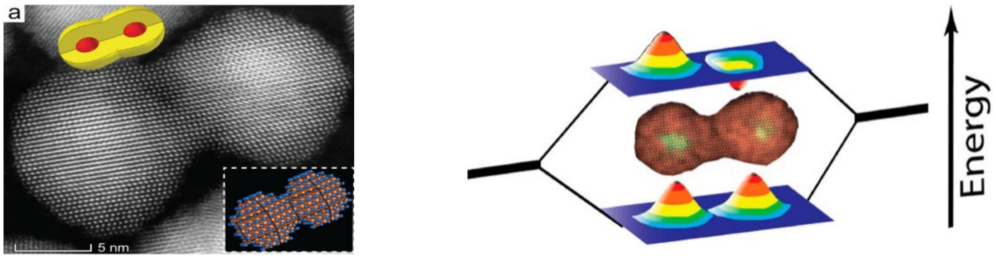


Fig. 1: Coupled homodimer molecule formed by fusing two core/shell colloidal quantum dots. Left: A high resolution electron microscopy image. Right: illustration of the hybridization of the electron wavefunction..

[1] Y.E. Panfil, M. Oded, U. Banin, , *Angew. Chem. Int. Ed.* **57**, 4274-4295 (2018).
[2] J. Cui, Y.E. Panfil, S. Koley, D. Shamalia, N. Waiskopf, S. Remennik, I. Popov, M. Oded, U. Banin, *Nature Comm* **10**, 5401 (2019).
[3] S. Koley, J. Cui, Y.E. Panfil, U. Banin, *Acc. Chem. Res.* **54**, 1178 (2021).

Keynote	Daniel Mandler	HUJI	Male	Professor

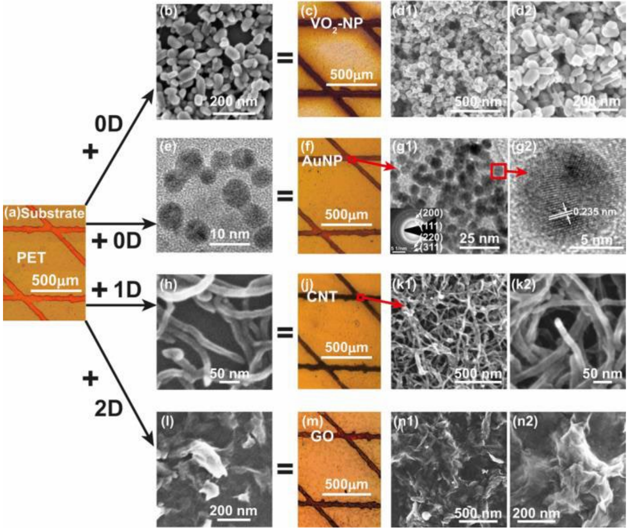
From Nano to Nano: A Different Approach for the Formation of Thin Films of Nanomaterials

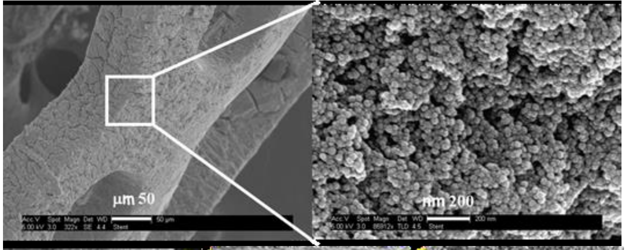
Daniel Mandler
Institute of Chemistry, The Hebrew University of Jerusalem
Jerusalem 9190401, Israel
Daniel.mandler@mail.huji.ac.il

The formation of thin films made of nanomaterials is relevant to numerous areas such as energy storage, electro- and thermo-coatings, and coating of implants. Coatings can be made from the gaseous or liquid phase. Electrochemistry is a very appealing approach for coating conductive materials as it can be easily applied to complex geometries. Electrochemical deposition (ED) dates back to Faraday and is a well-established approach for producing coatings. This presentation will summarize novel ED approaches, where nanostructured films are deposited, starting with nanomaterials as building blocks, instead of molecular or ionic species. We term it "from nano to nano” as we cause nanomaterials dispersed in solution to deposit and maintain their unique nanoscale properties. It is achieved *via* destabilizing the nano-objects in the dispersions by applying electrochemical potential or current, which diminishes interparticle repulsion.

Four different mechanisms have been explored, so far, for the ED of nanomaterials: (a) Direct redox induced deposition; (b) Indirect pH and ionic strength induced deposition; (c) Matrix induced co-deposition, and (d) Electrophoresis. With the latter three mechanisms, the “nano to nano” approach can be applied to electrochemically inactive and non-conductive nanomaterials.

Different applications will be demonstrated such as the coating of medical devices, electrochromic windows, and the formation of high-capacity supercapacitors.





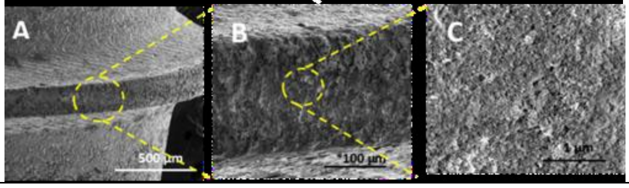


Figure: Top – electrochemical deposition of various nanomaterials by altering the ionic strength. Center – Coating of a stent with Latex nanoparticles. Bottom – Coating of an orthopedic implant by hydroxyapatite.

References

Levy, I.; Magdassi, S.; Mandler, D. Electrochim. Acta 2010, 55, 8590-8594.
Liu, L.; Layani, M.; Yellinek, S.; Kamyshny, A.; Ling, H.; Lee, P. S.; Magdassi, S.; Mandler, D. J. Mater. Chem. A 2014, 2, 16224-16229.
Geuli O., Metoki N., Eliaz N. and Mandler D., Adv. Funct. Mater. 2016, 26, 8003-8010.
Liu, C.; Yi, L.; Magdassi, S.; Mandler, D., Nanoscale, 2017, 9, 485–490.
Rastogi, P. K.; Sarkar, S.; Mandler D., Appl. Mater. Today, 2017, 8, 44-53.
Geuli O.; Metoki N.; Zada T.; Reches M.; Eliaz N.; Mandler D., J. Mater. Chem. B, 2017, 5, 7819-7830.
Geuli O.; Lewinstein I.; Mandler D., ACS Appl. Nano Mater., 2019, 2, 2946-2957.
Geuli, O.; Mandler, D., Chem. Comm., 2020, 56, 379-382.
Liu, L.; Mandler, D., Electrochemistry Communications 2020**,** *120*, 1388-2481.

Invited	Menny Shalom	BGU	Male	Professor

Photo- and electrocatalyst development for catalytic oxidation of organic molecules to value-added chemicals

Menny Shalom
Department of Chemistry, Ben-Gurion University of the Negev, Beer-Sheva, Israel

Photoelectrochemical cells (PECs) have been developed as environmentally friendly systems that can directly utilize photogenerated electron-hole pairs for water splitting, fuel production, conversion of carbon dioxide, and pollutant degradation. Most reports on the photocatalytic or PEC hydrogen (H2) evolution via water splitting have focused on the H2 reduction half-reaction by generating on the photoanode non-valuable oxygen or using sacrificial agents to consume the generated h+, resulting in a significant waste of energy. Lately, much effort is invested into the synthesis of valuable chemicals on the photoanode while retaining the production of H2 on the cathode.

Over the past few years, polymeric carbon nitrides (CN) attract widespread attention due to their outstanding electronic properties, which have been exploited in various applications, including photo- and electro-catalysis, heterogeneous catalysis, CO2 reduction, water splitting, light-emitting diodes, and PV cells. CN comprises only carbon and nitrogen, and it can be synthesized by several routes. Its unique and tunable optical, chemical, and catalytic properties, alongside its low price and remarkably high stability to oxidation (up to 500 °C), make it a very attractive material for photoelectrochemical applications. However, only a few reports regarded CN utilization in PECs due to the difficulty in acquiring a homogenous CN layer on a conductive substrate and our lack of basic understanding of the intrinsic layer properties of CN.

This talk will introduce new approaches to grow CN layers with altered properties on conductive substrates for photoelectrochemical applications. The growth mechanism and their chemical, photophysical, electronic, and charge transfer properties will be discussed. I will show the utilization of PEC with a CN-based photoanode as a stable and efficient platform for the oxidation of organic molecules to added-value chemicals, with hydrogen co-production. The second part of the talk will be focused on the electrocatalytic oxidative upgrading of organic molecules by NiFe-oxide into valuable chemicals.

Invited	Gil Markovich	TAU	Male	Professor

Anisotropic Optical Activity in Chiral Tellurium Nanocrystals

B. Reuven[1], A. Movsesyan[2,3], A. Govorov[2], and G. Markovich[1]

[1]School of Chemistry, Tel Aviv University, Tel Aviv, Israel

[2] Department of Physics and Astronomy and Nanoscale and Quantum Phenomena Institute, Ohio University, Athens OH, USA

[3] Institute of Fundamental and Frontier Sciences, University of Electronic Science and Technology of China, Chengdu, China

The anisotropic chiroptical activity of chiral nanorod-shaped tellurium nanocrystals was studied experimentally via circular dichroism (CD) measurements of macroscopically aligned samples. Te nanorods with chiral, twisted prismatic shapes and aspect ratio of ~4 were synthesized using the chiral ligand D-Penicillamine and the surfactant sodium dodecyl sulfate. The anisotropy of their optical activity was studied at two different configurations with the long axis of the nanorods oriented parallel and perpendicular to the CD probe beam. The parallel alignment was achieved in aqueous suspension using an alternating electric field that acts on their polarizability anisotropy, estimated to be 3.8×10-30 F m2. The perpendicular orientation was measured in a film of the nanorods, prepared at a liquid water-organic interface such that the nanorods are deposited on a substrate with their long axis in-plane. Finite-element electromagnetic simulations reproduce well the experimental CD spectra, demonstrating that the optical activity is dominated by the chiral shape-related Mie-type resonances. Both the experimental results and simulations show that the CD spectrum is practically inverted between the two light incidence orientations, a phenomenon that appears general to twisted anisotropic nano-objects.

Contributed	Arie Borenstein	Ariel U	Male	Senior Lecturer

Recent progress in Laser Processing of Carbon nanomaterials

A. Borenstein [1]

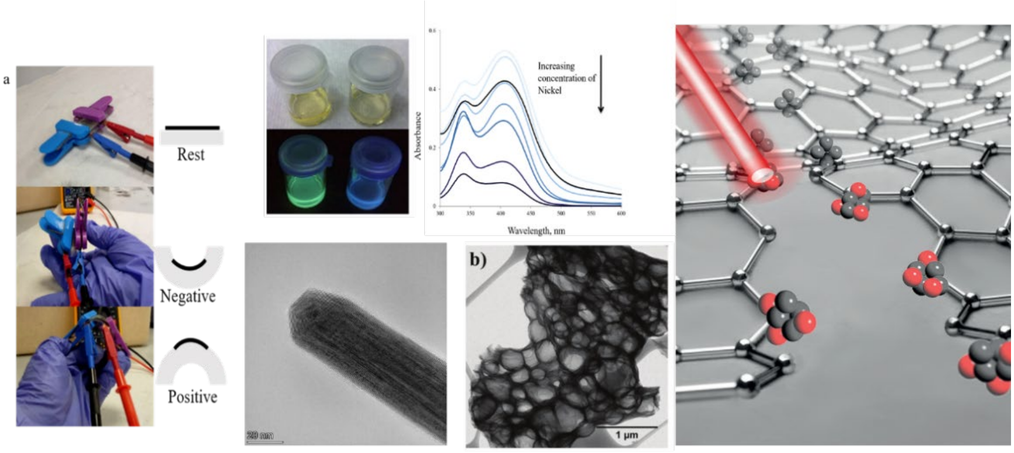
[1]Department of Chemical Sciences, Arie University, Ariel, Israel

Carbon materials, especially in the nanoscale, are becoming the preferred materials of the future. In the past decade, laser-induced carbonization emerged as a simple, eco-friendly, and cost-effective synthesis method of high-grade nanocarbons. A major advantage of laser-synthesis is the possibility of fine-pattern films according to the requirements of the application and tunability with regard to laser-wavelengths and energy input. The precursors are directly carbonized on the substrate, and their properties are adjusted by careful selection of the laser parameters. The possibility of patterning enables new potential applications for carbons such as micro charge-storage devices, catalytic electrodes, or electrochemical sensors.

The most studied precursor for laser-induced reaction is graphene-oxide. Its laser-assisted conversion into reduced graphene oxide (rGO) and the potential application of the product were comprehensively studied. Upon laser irradiation, oxygen groups and carbon dioxide gas leave the sample with high pressure. The pressure expands the gaps between the GO sheets and reduces GO (rGO) in the 3D matrix. The produced films demonstrate high surface areas and electrical conductivities.

In recent years, different research groups around the globe use laser treatment to carbonize and graphitize other carbon precursors. Expanding the range of precursors widens the

optional properties of the laser-induced carbons. Using laser processing, we successfully developed carbon nanodots, CNT, MOF, and MXene-based composites. Additionally, a better understanding of the laser-driven process allows the design of improved carbons and composites for advanced applications



[1] M. K. Yadav, A. Borenstein, Carbon, **199**, 208 (2022).
[2] A. Dutta, K. Sathyan, D. Sharon, A. Borenstein, FlatCheml, **33**, 100378 (2022).
[3] A. Borenstein, V. Strauss, M. D. Kowal, M. Anderson, R. B. Kaner,
Small, 15, **2019**, 1904918

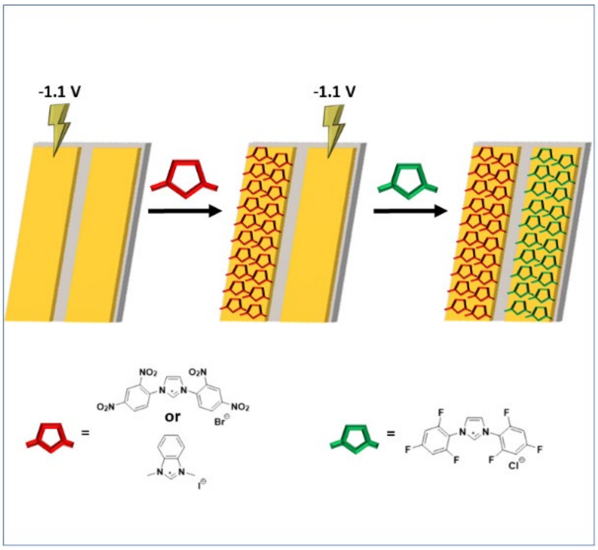
Contributed	Iris Berg	HUJI	Female	PhD student

Selective Deposition of N-Heterocyclic Carbene Monolayers on Designated Au Microelectrodes Within an Electrode Array

Iris Berg[1,2], Einav Amit[1,2], Wenhao Zhang[3], Rajarshi Mondal[1], Hadar Shema[1,2], Vitaly Gutkin[2], Tatyana Kravchuk[4], F. Dean Toste[2], Zackaria Nairoukh[1] and Elad Gross[1,2]*

[1] Institute of Chemistry, The Hebrew University, Jerusalem 91904, Israel
[2] The Center for Nanoscience and Nanotechnology, The Hebrew University, Jerusalem 91904, Israel
[3] Department of Chemistry, University of California, Berkeley, California 94720, United States
[4] Surface Science Laboratory of Solid-State Institute, Technion - Israel Institute of Technology, Haifa, Israel

The incorporation of organic self-assembled monolayers (SAMs) in microelectronic devices requires precise spatial control over the self-assembly process. In this work, selective deposition of N-heterocyclic carbenes (NHCs) on specific electrodes within a two-microelectrode array was achieved using pulsed electrodeposition.[1] Analysis of the NHC-coated electrode arrays revealed a distinctive pattern of a single type of NHC on each electrode, forming a dense and homogenous monolayer. The impact of NHC monolayers on the electrodes' work function was evaluated using Kelvin probe force microscopy, which showed that the adsorption of different NHCs on neighboring electrodes led to variations in their work function values. The presented method therefore enables to selectively coat specific electrodes in an electrode array by NHC monolayers for tuning their chemical and electronic functionality.



(1) Amit, E.; Dery, L.; Dery, S.; Kim, S.; Roy, A.; Hu, Q.; Gutkin, V.; Eisenberg, H.; Stein, T.; Mandler, D.; et al. Electrochemical Deposition of N-Heterocyclic Carbene Monolayers on Metal Surfaces. *Nat. Commun.* **2020**, *11* (1), 1–10.

Contributed	Rotem Azoulay	Technion	Female	PhD student

Spatially Controlled Atomic Layer Deposition within Polymer Templates for Multi-Material Nanorods and Nanowires Fabrication

R. Azoulay[1], T. Segal Peretz [1]

[1]Department of Chemical Engineering, Technion – Israel Institute of Technology, Haifa, Israel

Today’s nanofabrication techniques require multistep and costly processes in order to fabricate complex, multi-materials nanostructures. Performing atomic layer deposition (ALD) within polymeric templates can offer a simple solution for nanostructure fabrication. In this process, named sequential infiltration synthesis (SIS), high partial pressures and long exposures times lead to inorganic materials growth within polymers. Sequential polymer removal results in polymer-templated inorganic nanostructure. While SIS shows great potential in fabricating large variety of structures, it is currently limited to a single material growth process.

In this research, we demonstrated, for the first time, multi-material SIS process with control over the spatial location of each material and fabricate heterostructure nanorods and nanowires. We studied SIS within self-assembled block copolymer (BCP) films and electrospun polymer fibers and developed multi-material SIS, where two metal oxides are grown together in a single process, with precise control over their location within the polymer template. We used cylinder forming poly (styrene-block-methyl methacrylate) (PS-b-PMMA) films and electrospun PMMA as the polymeric template and DEZ (diethyl zinc), TMA (trimethyl aluminum) as the organometallic precursors. We achieved control over the growth location of each metal oxide by tuning the organometallic precursors diffusion time, forming heterostructures after polymer removal. A short exposure of the first precursor resulted in a limited growth only at the outer part of the polymer, while a long exposure of the second precursor enabled it to reach the full depth of the polymer besides the section which was already occupied by the first precursor. An exposure to water completed the cycle. We demonstrated this process on BCP films to achieve AlOx-ZnO nanorods arrays (Figure 1) and on polymer fibers to achieve AlOx-ZnO fibers. We performed structural characterization using scanning and transmission electron microscopy (SEM and TEM, respectively) to characterize the nanowires and nanorods as well as three-dimensional characterization scanning TEM (STEM) tomography and energy-dispersive X-ray spectroscopy (EDS) STEM tomography in order to probe the structure and the chemical composition in 3D. This research opens new pathways for multi-materials nano scale structure fabrication through ALD-based growth within polymers.

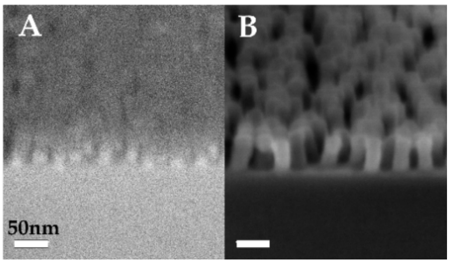


Fig. 1: AlOx-ZnO nanorods array: cross-sectional views A) using secondary electron in-lens detector and B) EsB detector.

[1] R. Azoulay et al., Small, **15**, 1904657 (2019).
[2] R. Azoulay et al., ACS Appl. Nano Mater., **5**, 7228 (2022).