Report

on the

The Hydrogen Energy Project

within the

Grand Technion Energy Program

supported by the

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GTEP 2016 Overview

Founded in 2007, The Nancy and Stephen Grand Technion Energy Program (GTEP) is a global pioneer in energy research and education. GTEP activities generate a flow of scientific discoveries and educational initiatives in the field of energy research.

GTEP brings together an exceptional cross-disciplinary community of energy scholars, conducting basic research and the development of applications to enable the effective generation, use and storage of energy for the future.

In 2016, Prof. Yoed Tsur of the Technion Faculty of Chemical Engineering became GTEP Director. His research pioneers fuel cell technologies and electro-ceramics. In addition, GTEP is supervised by a multi-disciplinary committee of faculty members from seven departments.

In its ninth year, GTEP is consolidating its achievements and building on its strengths. Presently, GTEP is identifying additional multidisciplinary research areas that could be supported to maximize energy research at Technion. To this end, GTEP is exploring new funding sources for new initiatives.

The formation of strategic research agreements with top academic institutes has been a part of the GTEP mandate since its inception. Today, GTEP is seeking further enrichment of its global network of collaboration, including joint projects; student exchange; and dual mentor research training programs for international students and postdoctoral scholars.

At this time, GTEP supports research in hydrogen technologies; advanced batteries, fuel cells and other storage and conversion means; photovoltaics; optics and light manipulation; biofuels; smart grids'; and computational research for energy applications. A future emphasis will include an integration of converging technologies (nano-, bio-, and info-technologies) within energy research. Additional emphasis will be put on energy optimization. The Technion is a worldwide leader in distributed systems and networking research. It is also strong in optimization and in game theory. Combining those strengths in the framework of energy research can yield a very strong impact in this important area.

During the past nine years around 60 Technion faculty members have been supported through GTEP's funding channels, which include seed money grants; graduate student and postdoctoral fellowships; facilitation of events; and the use of the GTEP central laboratories and equipment.

Among GTEP achievements is its role in the recruitment of 14 new faculty members to Technion and energy research.

The Interdisciplinary Energy Graduate Studies Program was the first academic program in Israel to offer advanced degrees in energy for excellent students. GTEP provides students with the essential infrastructure and provides the foundation for a multidisciplinary approach to energy studies through central research facilities; data sharing; seminars and conferences and generous scholarships. The aim now is to further increase the number of international graduate students and to establish more research partnerships with world-class institutes, to support student exchange and dual-mentor training.

In the 2015-2016 academic year, GTEP had 41 registered students, of whom 22 were MSc students and 19 were PhD students.

Technion's Natural Gas and Petroleum Engineering ME Program also operates through GTEP and will celebrate the graduation of its third generation this year. So far there are 50 graduates of this unique program that should become the backbone of an important emerging industry in Israel.

In recent years, GTEP outreach activities for high-school and undergraduate students included undergraduate involvement in leading international competitions. This year will be the fourth consecutive year that a Technion student team competes in the Formula SAE Race Car Design Competition. The Technion Formula team keeps improving, and during the summer of 2016 it participated in two international competitions, winning 8^{th} and 9^{th} places. During 2017, the new car will feature a smaller and lighter engine. Also with GTEP support, Technion students were the first Israeli team to take part in the International ¼ Scale Tractor Student Design Competition in the US.

The Nancy and Stephen Grand Energy Laboratories and Headquarters are currently in the final stages of construction. These facilities will give GTEP a physical presence at Technion, and will serve as the multidisciplinary energy research headquarters.

As it completes its first decade of activity, the game-changing and innovative educational paradigm established through the GTEP vision has become an exemplary model worldwide. The global energy challenge is likely to intensify in coming years and is set to remain a top priority in research and education for the coming decades. GTEP remains a critical national and global center for the advance of urgently needed energy solutions.

The support of the Adelis Foundation plays an integral role in the progress that has been made by the Grand Technion Energy Program and its vision for the future.

The Hydrogen Energy Project at Technion
Technion – Ben-Gurion University
Collaborative Renewable Energy Research

Introduction

Through the generous support of the Adelis Foundation, the Grand Technion Energy Program (GTEP) has been able to promote, support and expand research and development activities in renewable energy at the Technion, as well as to establish collaborative research initiatives with scientists from Ben-Gurion University of the Negev (BGU). These goals have been met through the establishment and support of the Hydrogen Technologies Research Laboratory (HTRL) at the Technion, purchase of specialized energy equipment which serves diverse multi-faculty research groups, and through the joint Technion-BGU seed funding research grants selected by the annual call for proposals.

At Technion, the support of the Adelis Foundation is focused on the Hydrogen Generation project, which aims to innovate clean and efficient methods for the production, storage, conversion and application of hydrogen energy. The Hydrogen Technologies Research Laboratory (HTRL) was established as part of this project, with joint funding by GTEP, the Adelis Foundation and the Solar Fuels I-CORE initiative.

The hydrogen-generation project addresses high-potential research exploring efficient and cost-effective production of hydrogen from renewable sources such as water and solar energy, as well as biomass, hydrogen storage in lightweight materials, efficient and low cost hydrogen fuel cells and methods of converting hydrogen into carbon-free electricity.

Current research is targeting development of technologies that will enable large-scale generation of hydrogen by solar water splitting technologies (photo electro-chemical cells).

To date the joint Technion – Ben-Gurion University Collaborative Renewable Energy seed funding program has supported 12 collaborative research groups on topics ranging from light harvesting in molecular systems on a nano-scale, to enhanced hydrogen composite absorption, and polymer solar cells to theoretical investigation in organic photovoltaics.

Research activities supported by the Adelis Foundation through this program led to high-impact discoveries and publications in leading journals.

Hydrogen Technologies Research Central Laboratory (HTRL)

The Technion Hydrogen Technologies Research Laboratory (HTRL) is a central Technion facility established jointly by GTEP, I-CORE and Adelis Foundation temporarily located at the "tromi 3" building; the construction of the permanent facility is progressing. It will be completed during 2017.

The activity in this laboratory is supervised by Prof. Avner Rothschild of the Faculty of Materials Science and Engineering and Dr. Yifat Nakibli, the laboratory engineer.

The HTRL laboratory supports efforts for the discovery and development of innovative hydrogen energy technologies. Students and researchers from different disciplines (chemistry, biology, chemical engineering, materials science and others) make use of the laboratory’s facilities to explore novel applications for the production of hydrogen from renewable natural resources such as water and solar energy that will be efficient and cost-effective in the conversion and storage of large amounts of hydrogen.

Activities at HTRL focus on the development of new materials, photocatalysts, and innovative electrodes that will enhance photo-electrochemical and fuel processing systems using deposition methods (such as thin film solar cell fabrication); electrical characterization; and photo-electrochemical sample analysis. The advanced analytical equipment at the laboratory is unique in its flexibility and capacity to accommodate studies in hydrogen energy production as well as research in other fields. This is a central Technion facility supporting students and faculty as well as scientists from industry.

The laboratory has approximately 30 users from nine research groups in various disciplines: Prof. Avner Rothschild of the Faculty of Materials Science and Engineering; Prof. Gideon Grader; Assoc. Prof. Yoed Tsur, Assistant Prof. Oz M. Gazit, Prof. Yaron Paz and Assistant Prof. Ofer Manor of the Faculty of Chemical Engineering; Prof. Noam Adir and Assistant Prof. Lilac Amirav of the Faculty of Chemistry; Prof. Emeritus, Michal Green of the Faculty of Environmental, Water and Agricultural Engineering; and Prof. Gadi Schuster of the Faculty of Biology.

HTRL Facilities

Solar Simulator (Abet Technologies, USA)

The Solar Simulator is a light source for testing photo-electrodes and photo-catalysts under standard illumination conditions. The Solar simulator is used for measuring the power output of photo-systems. The simulator can provide a 156 x 156 mm illuminated field.

Kelvin Probe (NRH020 KP Technologies)

The Nitrogen Relative Humidity Chamber is equipped with a non-scanning Kelvin probe, which is a non-contact, non-destructive vibrating capacitor device used to measure the work function of conducting materials or surface potential of semiconductors. This system is equipped with a high intensity mono-chromator light source (Horiba Jobin Yvon S.A.S) that enables measuring CPD at different wavelengths.

Ultrasonic Spray Deposition (ExactaCoat, Sono-Tek)

A fully-enclosed, programmable 3-axis robot integrated ultrasonic spraying system designed for depositing active layer solutions to produce thin films. ExactaCoat is designed for depositing active layer solutions, suspensions, and nano-suspensions for thin film solar cell production and active layers for PEM fuel cells solid and oxide fuel cells. The ExactaCoat is equipped with a hotplate up to 600 °C and controlled environment.

Dry/Wet Electrochemical Characterization Station (Ivium nStat + Small Solar Simulator)

A multi-channel Potentiostat/Galvanostat with an integrated impedance analyzer. The nStat has four potentiostats, and each potentiostat is a completely independent instrument. Combined with a small solar simulator, it allows measuring photo-systems that do not require a large area illuminated field (25 X25 mm).

Profilometer (DekTak Bruker)

A stylus (contact) profilometer is used to measure height differences (steps) on samples. DektakXT provides the ability to quickly and easily set up and run automated multi-site measurement routines to verify the precise thickness of thin films down to the nanometer scale. The DektakXT is also ideal for routine qualification of surface roughness.

Vinyl Anaerobic Chamber (Coy Lab products)

The vinyl anaerobic chamber provides a strict anaerobic atmosphere of 0-5 ppm using a palladium catalyst and hydrogen gas mix of 5%. The heavy-duty vacuum airlock allows sample transfer without changes to the internal atmosphere. The programmable airlock allows the user to tailor an interchange sequence ideal for their lab experiments.

Future Plans

Since mid-2014, the HTRL lab has been fully active, routinely operating and serving over 20 different research projects, experiments and systems. The lab has helped students establish systems for new projects and hopes to extend this service to other users. Recently, an anaerobic chamber was set up for new research in biology. Another feature was added to the Sonotek system: a sonicator-syringe which enables deposition of ceramic layers with spray pyrolysis. This method is becoming more applied and can extend the number of users for this facility, thus encouraging new research fields.

In the coming year, the group aims to expand its services and the number of users, remaining a focal facility used by scientists from industry and academia as a core-laboratory for innovative developments and research in the energy field.

Equipment supported through the Adelis Foundation

Potentiostat / Galvanostat / ZRA w/Auxiliary Electrometer
Equipment Location – Faculty of Chemical Engineering

Electrochemical impedance spectroscopy (EIS) is a very powerful tool for materials and simple systems' characterization. Using it to aid novel fuel cells development and for fuel cells and related component characterization requires high accuracy over a large frequency range. This must also be combined with the ability to measure at relatively high currents, i.e., at the 1 A regime. For this, GTEP has purchased the Gamry 3000, which can measure up to eight channels simultaneously, and which is capable of other complementary electrochemical measurements such as cyclic voltammetry. After thoroughly examination and comparison with five alternatives, measuring dummy cells that imitate real-world situations the tool proved to be the best in its class.

In vivo and in vitro fluorometer for analysis of photosynthetic material to be used in a bio-generator
Equipment Location – Schulich Faculty of Chemistry

In this research, scientists are attempting to use the natural photosynthetic capability to transform the energy of the sun into useful and completely clean chemical energy. For this purpose, various photosynthetic species (cyanobacteria, algae or plants) are used, which are modified in a way that will not harm their growth, but will enable harvesting of the light-driven flow of electrons – a bio-generator.

In order to assess the state of modified organisms, and their isolated membranes, the recently purchased PAM type fluorometer is used. This device enables researchers to follow the kinetics of electron transfer within the photosynthetic apparatus, in either wild-type or modified material, at all levels. The effect of added chemicals, such as inhibitors of Photosystem II on electron transfer can also be observed. This is due to the high quantum yield for fluorescence of Photosystem II, which is the major engine of the proposed bio-generator. The equipment is extremely important since it allows researchers to follow molecular events in whole cells, in a completely non-evasive manner – researchers can even use it on leaves still attached to a plant!

Ultrasonic spray deposition (ExactaCoat, Sono-Tek)
Equipment Location – The temporary Hydrogen Technology Laboratory

An additional required piece of equipment which was recently ordered is a spray deposition laboratory coating machine. This is the first materials synthesis equipment to be purchased for the hydrogen laboratory. This system is a fully-enclosed, with a programmable 3-axis robot and ultrasonic atomizing nozzles that enable scientists to deposit uniform, easily shaped targeted nanolayers of materials at very low flow rates without the clogging or overspray of expensive liquids in a fully contained, safe environment. This system provides the capability to develop a variety of new devices and hydrogen production systems.

Vertex: entry level potentiostat 1A@10V;
Equipment Location – The temporary Hydrogen Technology Laboratory

For the electrochemical measurements a potentiostat/galvanostat platforms such as Vertex: entry level potentiostat 1A@10V, offers a wide range of applications. This high power potentiostat with the high current output enables measurements on location and measurements of small signals.

Kelvin Probe (NRH020 KP Technologies)
Equipment Location: the temporary Hydrogen Technology Laboratory

Nitrogen Relative Humidity Chamber equipped with a non-scanning Kelvin probe (KP Technologies Ltd.), which is a non-contact, non-destructive vibrating capacitor device used to measure the work function of conducting materials or the surface potential of semiconductor or insulating surfaces. This system is equipped with high intensity monochromator light source that enable measuring CPD at different wavelengths.

Gas Valves and Vacuum Gauges for the Sieverts Apparatus

The Adelis Foundation also helped us to upgrade the Sieverts apparatus, which is located in the Faculty of Materials Science and Engineering and is used by the Solid State Thermodynamics group.

Sieverts apparatus allows measurements of thermodynamic parameters of hydrogen interaction with hydrogen-absorbing materials, and measurements of hydrogenation kinetics. The current research focuses on the hydrogenation cycling stability of the novel materials for hydrogen storage.

Cycling tests require that the Sieverts apparatus is kept running and performing cycling measurements for many days. These valves, which provide unprecedented accuracy and stability in low-flow gas applications are very reliable and suitable for this task.

Another purchase which was made for the upgrade of the Sieverts apparatus were several vacuum gauges, which were needed for expanding of the apparatus and improving its performance.

Differential Dilatometer DIL802 (TA instruments)
Equipment Location: Electroceramics and Nanotechnology Laboratory, at the Wolfson Department of Chemical Engineering

An instrument of high importance for research on energy conversion devices, as it measures the difference between the sample and the inert reference only and negates the influence of the measurement system expansion on the sample measurement. This measurement design is of particular benefit for dynamic temperature programs. The DIL802 in connected to a gas control system in order to perform measurements at different environments (air and fuel).

The research led by Prof. Tsur uses the differential dilatometer to investigate electro-chemo-mechanical challenges in fuel cells and stacks as part of cell design. Mechanical mismatch between adjacent layers due to thermal and chemical cycling is among the most problematic issues causing degradation.

XPS System – Surface Science Laboratory

In 2017 a new XPS system will be installed at the Surface Science laboratory. The scanning XPS microprobe VersaProbe III (PHI Physical Electronics, USA) system will be equipped with the following features:

- An aluminum monochromated x-ray primary source with a beam size that can be varied from 300 to 10 μm diameter;

- A scanning X-ray beam induced secondary electron images (SXI) option with a field of view of 700*700 μm^2;

- An ability of chemical state imaging and mapping of surface sample (lateral resolution of 4-5 μm);

- An ultra violet integrated source allows ultra violet photoelectron spectroscopy (UPS) analysis for a direct measurement of valence band and work function of materials;

- The ability of in situ sample cooling (down to -140°C) or heating (up to 800°C).

The Versaprobe III system presents also the ability for depth profiling materials by three different methods:

- An angle resolved XPS (AR-XPS) analysis to depth profile by tilting the sample without damaging the surface, till about 15nm depth;

- A monoatomic Ar+ ion gun sputtering used for depth profiling semiconductor materials or metal oxide;

- A cluster Arn+ ion gun sputtering used for depth profiling organic based structures.

The versatility of the VersaProbe III will provide analytical and research services essential for progress of many academic research groups and industries ongoing activities in the means of surface science understanding.

Laboratory Readiness

In July 2016, a laboratory site review was performed by a PHI Engineer representative.

Environmental specifications as vibrations, acoustic noise, magnetic fields and temperature stability and humidity were checked and were found in accordance to PHI specifications.

System utility requirements as compressed air and dry nitrogen are in agreement with PHI specifications.

In order to avoid floor weight surcharge two decentralized plates were purchased in accordance to PHI recommendations.

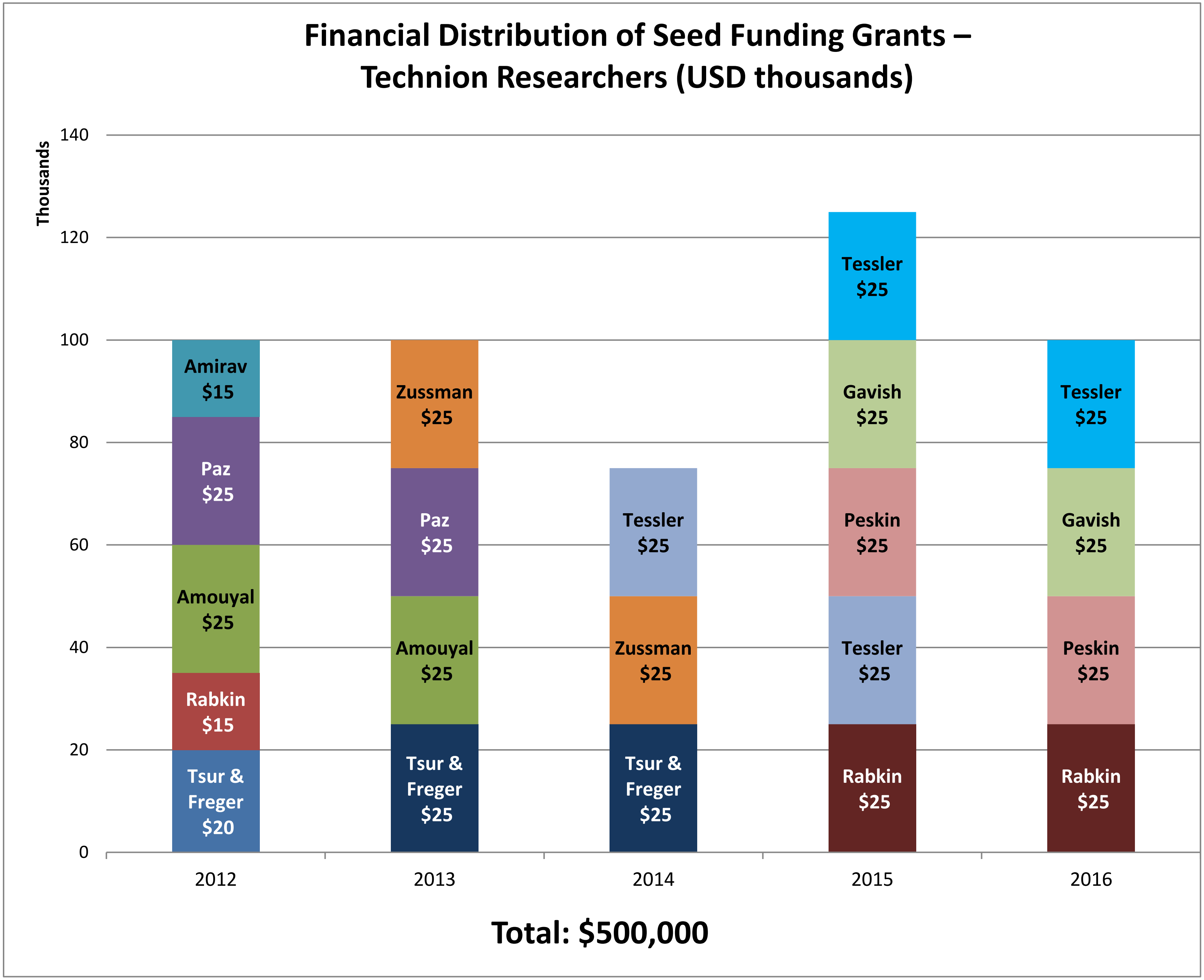
Technion – Ben-Gurion University Seed Funding Program

The goal of the Technion – Ben-Gurion University Seed Funding Program, supported by the Adelis Foundation, is to expand collaborative research in renewable energy between the two institutes.

The seed funding program has supported 12 collaborative Technion – BGU research projects in the total amount of $500,000.

Summary Collaborative Technion – BGU Research Groups the Adelis Foundation Program for Seed Funding 2012 – 2016

PI Technion	PI Ben Gurion Univ.	2012	2013	2014	2015	2016
mouyal, rials Sci. and Eng.	elbstein, rials Eng.	**hancement of the thermoelectric conversion efficiency ($(bTe)_x(Ag_2Te)_{1-x}$ compounds upon controlled nano-scal precipitation for renewable energy applications**				
az, mical Eng.	Veinstock, mistry	**o-engineered composite materials for photocatalytic wa splitting**				
abkin, rials Sci. and Eng.	egev, mical Eng. -Bar, mical Eng.	**alyzed hydrogen storage in Magnesi – Carbon nanocomposites**				
nirav, mistry	ar-Sadan, mistry	**Bi-Metallic Co-catalysts for Efficient Photocatalytic Hydrogen Production**				
sur, mical Eng.	orin, mical Eng.	**New Concepts for the Preparation of embrane-Catalytic Electrode Fuel Ce Systems**	**evelopment, Analysis and Integration of toelectrolytic System Components for t Generation of Solar Hydrogen**			
eger, mical Eng.	ettelheim, mical Eng.					
ussman, hanical Eng.	atz, erushalmi- Rozen,		**no-Structured Functional Fibers as Activ Layers in Organic-Solar Cells**			
essler, trical Eng.	okari, mistry			**hostructures of Metal Oxide Chalcogeni s Active Material for Solution Processed Photovoltaic**		
avish, ematics	chelis, r Energy & Environ. ics				**eory for Interrelations between Change Dynamics an Bulk Morphology in Organic Photovoltaics**	
eskin, mistry	ubi, mistry				**Light-harvesting in molecular systems: the role of ironment in optimizing the efficiency of energy trans on the nano-scale**	
E. Rab Materials Sci. and E	O. Reg Chemical E				**Enhanced Hydrogen Absorption and Desorption on Composites of Graphene Derivatives in Magnesium**	
N. Tess Electrical E	M. Schvartzm Materials E				**olymer Solar Cells with Nanoimprinted Heterojunctio Morphology Scaled at the Exciton Diffusion Length**	


Financial Distribution of Seed Funding Grants – Technion Researchers (USD thousands)
Thousands
140
120
100
80
60
40
20
0
Tsur & Freger $20
Rabkin $15
Amouyal $25
Paz $25
Amirav $15
Tsur & Freger $25
Amouyal $25
Paz $25
Zussman $25
Tsur & Freger $25
Zussman $25
Tessler $25
Rabkin $25
Tessler $25
Peskin $25
Gavish $25
Tessler $25
Rabkin $25
Peskin $25
Gavish $25
Tessler $25
2012
2013
2014
2015
2016
Total: $500,000

Scientific Papers/ Publications

GTEP infrastructure and support for energy related research continues with high-impact discoveries and publications in leading journals.

Prof. Nir Tessler's research team from the Department of Electrical Engineering recently introduced a method to increase the efficiency of thin film solar cells by over 30 percent. The band-gap enhanced photovoltaic structure reduces the limitations in circuit voltage found in many physical processes through a new device structure. Called ‘device synthesis,' the new methodology is predicted to enhance the open circuit voltage of organic solar cells and of thin-film solar cells in general. Researchers expect that solar cell power efficiency of 50 percent will eventually be achieved. Results from the patented breakthrough were published in the Journal of Applied Physics.

At the Faculty of Chemistry, Prof. Lilac Amirav's research team has made significant progress in photocatalytic water splitting, demonstrating a 100 percent light-to-hydrogen gas conversion efficiency. The research focusses on a unique design of innovative, nano-scale particles, which leverage nano phenomena for improved activity, as well as introducing methodologies for the construction of sophisticated heterostructures. The results were published in the scientific journal Nano Letters.

A multidisciplinary GTEP team recently developed a bio-photo-electro-chemical (BPEC) cell that produces electricity and hydrogen from water using sunlight. Using a simple membrane extract from spinach leaves, the raw material of the device is water, and its products are electric current, hydrogen and oxygen. The unique combination of a man-made BPEC cell and plant membranes, which efficiently absorb sunlight and convert it into a flow of electrons, opens the way for new renewable energy technologies. The research was conducted by GTEP doctoral students, Gadiel Saper and Dan Kallmann under the guidance of Prof. Noam Adir, Prof. Gadi Schuster and Prof. Avner Rothschild. The findings were published in Nature Communications.

In the 2015-2016 academic year Gadiel Saper's fellowship was supported through the Adelis Foundation.

The following are the list of scientific publications directly affiliated with the Adelis Foundation support:

2013

Y. Amouyal, “On the role of lanthanum substitution defects in reducing lattice thermal conductivity of the AgSbTe2 (P4/mmm) thermoelectric compound for energy conversion applications”, Computational Materials Science. 78 (2013) 98

2014

V. Halperin, G. E. Shter, V. Gelman, D. M. Peselev, M. Mann-Lahav and **G. S. Grader**: Catalytic activity of electrospun Ag and Ag/carbon composite fibres in partial methanol oxidation. Catalysis Science & Technology. Nov 2014. appears online: DOI: 10.1039/C4CY01341G

E. Joseph and **Y. Amouyal**: Enhancing thermoelectric performance of PbTe-based compounds by substituting elements: a first-principles study, submitted; J. Elect. Mater. Oct 2014. Appears online: DOI: 10.1007/s11664-014-3416-7

Michael Volokh, Mahmud Diab, Osnat Magen, Ilan Jen-La Plante, Kobi Flomin, Pazit Rukenstein, **Nir Tessler**, and Taleb Mokari: Coating and Enhanced Photocurrent of Vertically Aligned Zinc Oxide Nanowire Arrays with Metal Sulfide Materials. ACS Appl. Mater. Interfaces. 2014,6,13594-13599. Appears online: DOI: 10.1021/am502976v

Malka Rochkind, Sagi Pasternak and **Yaron Paz**, Using Dyes for Evaluating Photocatalytic Properties: A Critical Review, Molecules 2015, 20, 88-110; doi: 10.3390/molecules20010088.

Emanuelle Goren, Mariana Ungureanu, Raul Zazpe, Marcelo Rozenberg, Luis E. Hueso, Pablo Stoliar, **Yoed Tsur**, and Fèlix Casanova: Resistive switching phenomena in TiOx nanoparticle layers for memory applications. Applied Physics Letters 2014,105,143506. Appears online: DOI: 10.1063/1.4897142

Neta Shomrat, Doron Haviv, **Yoed Tsur**: The correlation between non-stoichiometry and charge compensation in perovskites**.** J Electroceram. Oct 2014. Appears online: DOI: 10.1007/s10832-014-9975-4

2015

R. I. Pinhassi, D. Kallmann, G. Saper, S. Larom, A. Linkov, A. Boulouis, M.-A. Schoettler, R. Bock, **A. Rothschild**, **N. Adir** and **G. Schuster**, Photosynthetic membranes of Synechocystis or plants convert sunlight to photocurrent through different pathways due to different architectures, PLoS ONE 10(4):e0122616 (2015).

Philip Kalisman, Lothar Houben, Eran Aronovitch, Yaron Kauffmann, Maya Bar-Sadan and **Lilac Amirav***; “The Golden Gate to Photocatalytic Hydrogen Production”. J. Mat. Chem. A. 2015, 3, 19679-19682.

Eran Aronovitch, Philip Kalisman, Shai Mangel, Lothar Houben, **Lilac Amirav**, and Maya Bar Sadan; “Designing Bimetallic Cocatalysts: a Party of Two”. J. Phys. Chem. Lett. 2015, 6 (18), pp 3760–3764.

E. Joseph and **Y. Amouyal**; “Towards a predictive route for selection of doping elements for the thermoelectric compound PbTe from first-principles” J. Appl. Phys. 117 (17), 175102 (2015)

Sagi Pasternak and **Yaron Paz**: $BiYWO_6$: Novel Synthetic Routes and their Effect on Selectivity in Visible – Light Photocatalysis

Arsen G. Gevorkyan, Gennady E. Shter, **Gideon S. Grader**, Rapid thermal processing of electrospun PbZr0.52Ti0.48O3 nanofibers, Thermochimica Acta 605 (2015) 107–114

V.Halperin, G. E. Shter, V. Beilin and **G. S. Grader**, "Mesoporous K/Fe-Al-O Nanofibers by Electrospinning of Solution Precursors", Journal of Materials Research, 30 (20), 3142-3150, 2015. (DOI: 10.1557/jmr.2015.296) * Selected for Journal cover page

Neta Shomrat, Sioma Baltianski, Clive A. Randall, **Yoed Tsur,** Flash sintering of potassium-niobate, Journal of the European Ceramic Society 35 (2015) 2209–2213

2016

Philip Kalisman, Yifat Nakibli and **Lilac Amirav**, Perfect Photon-to-Hydrogen Conversion Efficiency, *Nano Lett.*, 2016, *16* (3), pp 1776–1781, 2016.

Eran Aronovitch, Philip Kalisman, Lothar Houben, **Lilac Amirav** and Maya Bar-Sadan, Stability of Seeded Rod Photocatalysts: Atomic Scale View, Chem. Mater. 2016, 28, 1546−1552.

Nir Gavish and Arik Yochelis, Theory of Phase Separation and Polarization for Pure Ionic Liquids, Journal of Physical Chemistry Letters, 7 (7), pp 1121–1126, 2016.

R. Gloukhovski, **V. Freger** and **Y. Tsur**; A Novel Composite Nafion/Anodized Aluminum Oxide Proton Exchange Membrane*, Fuel Cells* 16, 2016, No. 4, 434–443.

Robert Gloukhovski, **Yoed Tsur** and **Viatcheslav Freger**, A Nafion-filled Polycarbonate Track-Etched Composite Membrane with Enhanced Selectivity for Direct Methanol Fuel Cells, accepted for publication in Fuel Cells.

Robert Gloukhovski, **Viatcheslav Freger**, **Yoed Tsur,** Pore-filling composite organic proton exchange membranes A Beginner’s Guide, under review.

Céline Bounioux, Ron Avrahami, Gleb Vasilyev, Nilesh Patil, **Eyal Zussman**, and Rachel Yerushalmi – Rozen; Single-step electrospinning of MULTI WALLED Carbon nanotubes - POLY(3-OCTYLTHIOPHENE) hybrid nano-fibers, *Polymer,* March 2016, Pages 15–21.

Efrat Ruse, Svetlana Pevzner, Ilan Pri Bar, Roey Nadiv, Vladimir M. Skripnyuk, **Eugen Rabkin** and Oren Regev; Hydrogen Storage and Spillover Kinetics in Carbon Nanotube-Mg Composites, International Journal of Hydrogen Energy, January 2016, Pages 2814–2819.

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A. Niv, M. Gross Koren, H. Dotan, **G. Bartal** and **A. Rothschild**, Separation of light confinement and absorption sites for enhancing solar water splitting, Journal of Materials Chemistry A 4, 3043-3051 (2016).

D. A. Grave, H. Dotan, Y. Levi, Y. Piekner, B. Scherrer, K. D. Malviya and **A. Rothschild**, Heteroepitaxial hematite photoanodes as a model system for solar water splitting, Journal of Materials Chemistry A 4, 3052-3060 (2016).

K. D. Malviya, H. Dotan, D. Shlenkevich, A. Tsyganok, H. Mor and **A. Rothschild**, Systematic comparison of different dopants in thin film hematite (a-Fe2O3) photoanodes for solar water splitting, Journal of Materials Chemistry A 4, 3091-3099 (2016).

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R. I. Pinhassi, D. Kallmann, G. Safer, H. Dotan, A. Linkov, A. Kay, V. Liveanu, **G. Schuster**, **N. Adir** and **A. Rothschild**, Hybrid bio-photo-electro-chemical cells for solar water splitting, Nature Communications 7, 12552 (2016).

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STOP PRESS

Technion researchers have developed a new method for the production of hydrogen from water using solar energy. The new method will make it possible to produce the hydrogen in a centralized manner far from the solar farm, cost-effectively, safely and efficiently.

Technion-Israel Institute of Technology researchers have developed a new approach to the production of hydrogen from water using solar energy. In findings published yesterday in Nature Materials, the researchers explain that this approach will make it possible to produce hydrogen in a centralized manner at the point of sale (for example, at a gas station for electric cars fueled by hydrogen) located far from the solar farm. The new technology is expected to significantly reduce the cost of producing the hydrogen and shipping it to the customer.

The study was led by Avigail Landman, a doctoral student in the Nancy & Stephen Grand Technion Energy Program (GTEP), and Dr. Hen Dotan from the Electrochemical Materials & Devices Lab, along with Dr. Gennady Shter from the Faculty of Chemical Engineering. Ms. Landman is working on her doctorate under the guidance of Prof. Avner Rothschild from the Faculty of Materials Science and Engineering, and Prof. Gideon Grader, Dean of the Faculty of Chemical Engineering.

The study published in Nature Materials was supported by:

- Israeli Centers of Research Excellence (I-CORE) for Solar Fuel Research (funded by the Planning and Budgeting Committee of the Council for Higher Education of Israel)
- Ministry of National Infrastructures, Energy and Water
- the European Fuel Cells and Hydrogen Joint Undertaking (FCH JU)
- the Grand Technion Energy Program (GTEP)
- Ed Satell
- Adelis Foundation.

ADELIS FOUNDATION – Grant for Hydrogen Energy Project Financial Statement						
	Year 1 2012 $	**Year 2 2013 $**	**Year 3 2014 $**	**Year 4 2015 $**	**Year 5 2016 $**	**Total $**
INCOME	**500,000**	**500,000**	**500,000**	**500,000**	**499,988**	**2,499,988**
EXPENDITURE						
Equipment						
Equipment for Catalyst Synthesis and Characterization	133,047	63,566				196,612
Analytical Tools	61,111	97,062	66,743			224,916
Equipment for Controlled Environment		8,331				8,331
X-ray Photoelectron Spectroscopy (XPS)					370,000	370,000
Subtotal Equipment Costs	194,157	168,959	66,743	-	370,000	799,859
Seed Grants for Collaborative Research	100,000	100,000	75,000	125,000	100,000	500,000
Workshops and Graduate Student Support		19,705	16,740	15,707	11,073	63,225
Construction			200,000			200,000
Faculty Research Allocations	126,383	129,852	120,097	119,356	118,491	614,178
Equipment Fund: for one new faculty member working within the framework of the Leaders in Energy Science Program	81,543	81,586		79,937	79,659	322,725
Total Costs	**502,083**	**500,101**	**478,580**	**340,000**	**679,223**	**$2,499,987**
BALANCE OF FUNDS	**($2,083)**	**($101)**	**$21,420**	**$160,000**	**($179,236)**	**$0**

The Technion

expresses appreciation to

Fondation Adelis

for its support of this project

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