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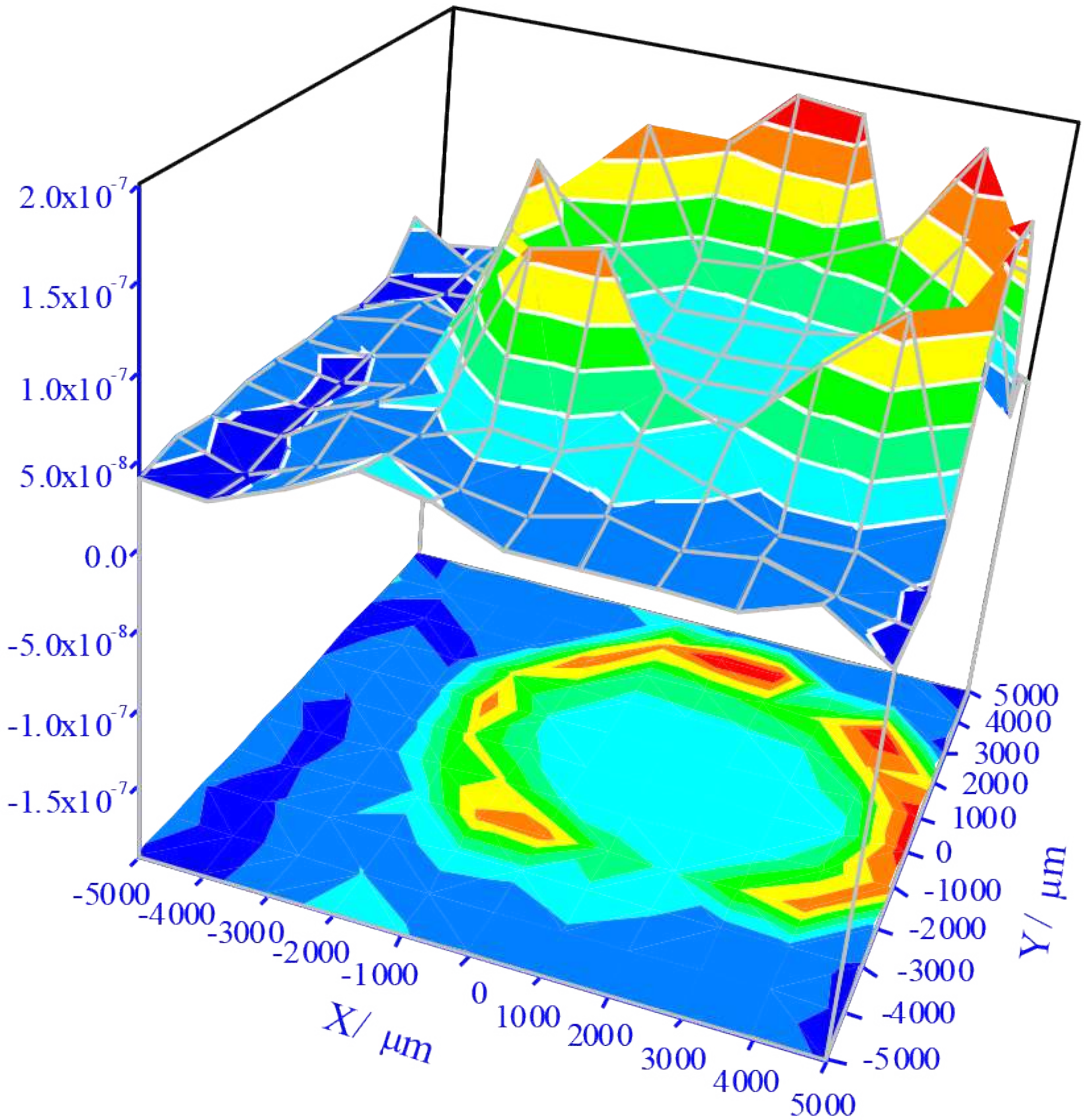
The Israel Chemist and Chemical Engineer

ICE



The Israel Chemical Society
(ICS: www.chemistry.org.il)

ASSOCIATION OF ENGINEERS, ARCHITECTS AND GRADUATES IN TECHNOLOGICAL SCIENCES IN ISRAEL

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Report

Dear Readers,

Welcome to the sixth issue of the Israel Chemist and Engineer (ICE) online magazine, a publication of the Israel Chemical Society (ICS). We hope you will find the magazine interesting and will be inspired to contribute to future issues.

Many of our ICS members are involved in research on vaccines against Covid-19 and so to inspire them, we have a timely account of Jonas Salk and the first vaccine against polio. We also have an interesting article on a new analytical tool called multiphoton electron extraction spectroscopy (MEES), a provocative account of terminology confusion in corrosion science and engineering, and reminiscences on the history of electron microscopy for materials at the Weizmann Institute and on thirty years of scientific and industrial cooperation between Israel and Mexico.

If you have suggestions for future editions, comments on the current issue, or would like to contribute an article, please contact me at gordon@biu.ac.il.

Arlene D. Wilson-Gordon

Professor Emerita

Chemistry Department, Bar-Ilan University

ICE Editor

Dear Colleagues,

These are challenging times for everybody, and it seems that the COVID-19 pandemic with its consequences will stay with us for quite some time, affecting every aspect of our life. From many perspectives, the year 2020 will be remembered as a "lost year." We all hope that life will get back on track as soon as possible. Many important events have been canceled or postponed indefinitely, including major international conferences, professional meetings, joint research projects, and anything else that requires international travel. Yet, Israel seems to be in a better situation than many other countries.

We were fortunate to hold the 85th Annual Meeting of the ICS last February in Jerusalem, just before most countries closed their borders, universities and schools closed their gates, and most scientists and students had to stay at home. We were also fortunate to host an extraordinary delegation of ten professors and twenty graduate students from Yale University. More details are available in my abbreviated conference report at the end of this issue.

I am satisfied that during my 12 years of service as ICS President, I have had the privilege of hosting six ACS presidents at our Annual Meetings, including Joseph Francisco, Nancy Jackson, Diane Schmidt, Donna Nelson, Bonnie Charpentier, and Luis Echegoyen. Furthermore, the relations between the ICS and ACS have recently intensified, as reflected by the signing of an agreement of collaboration between the two societies in August 2019 in San Diego. We have already started establishing an ACS Chapter in Israel, and we agreed to organize ACS-ICS joint symposia at the ACS National Meetings. We have also enhanced our relations with other national societies worldwide.

It is incredible that since the establishment of the ICS in 1933, we have kept the tradition of holding annual meetings with virtually no interruption. We plan to hold the 86th Meeting on February 2-3, 2021, at the David Intercontinental Hotel in Tel Aviv. Profs. Charles Diesendruck and Saar Rahav of the Technion's Schulich Faculty of Chemistry have taken on the responsibility of being chairpersons. We plan to host there a large delegation from Peking University and the Chinese Academy of Sciences.

I am sure you follow the intensification of awareness about inclusion and diversity issues that affects the entire globe, including the scientific world. For example, the NIH announced that it would remove their grants from researchers found guilty of harassment and sexual misconduct. The National Science Foundation (NSF) has also taken similar measures, requiring institutions to notify the agency of sexual misconduct findings. As part of the ICS activities related to these issues, we have recently joined the Royal Society of Chemistry initiative, signing the statement on inclusion and diversity in the chemical sciences: https://www.rsc.org/news-events/articles/2020/jun/id-joint-societies-statement/

Finally, I am happy to see the development of the ICE bulletin under the leadership of the Editor, Prof. Arlene Wilson-Gordon of Bar-Ilan University. I encourage you to contribute an article to the ICE on any topic you like, including popular science, history of science, reports on events, opinions, etc.

Enjoy your reading,

Ehud Keinan

President, the Israel Chemical Society

Chemistry for peace

This is a guest editorial by **Zafra Lerman**

Chemistry provides hope for peace and understanding in one of the most troubled regions of the world: the Middle East. Imagine walking into a room and encountering several round tables, each with 10 scientists from countries or regions whose governments are hostile to one another, and those scientists are discussing potential scientific collaborations with civility and friendship. At one table, for example, were representatives from Syria, Iraq, Iran, Gaza, Israel, Palestine, Saudi Arabia, Qatar, Egypt, and Jordan. Where else in the world can that happen? As one participant said, “Only at the Malta conferences.”

Every 2 years since 2003, the Malta conferences have provided an opportunity “to identify unique opportunities for collaboration to meet the scientific and technological challenges of the region.” The Malta IX Conference, which was held at the end of 2019 under the theme “Frontiers of Science: Innovation, Research, and Education in the Middle East,” was no different. The event gathered together scientists, entrepreneurs, postdocs, and students from 15 countries or regions from the Middle East, plus Morocco and Pakistan. These scientists participated in talks and workshops with several Nobel laureates to seek solutions to problems beyond geopolitics that this part of the world faces. To date, more than 700 Middle Eastern scientists and 16 Nobel laureates are in the Malta conferences network.

A challenge that has been a constant since the Malta conferences were launched is securing visas for participants. Although the preparations for the event started 2 years in advance, several participants from Iran, Egypt, Jordan, Syria, Gaza, Palestine, and Pakistan had still not received their visas 48 h before the conference was set to start. With the help of the Maltese minister for education and employment — and the organizers, who endured many sleepless nights — the authorities at the last minute agreed to issue visas to the scientists upon their landing in Malta.

Malta IX had a makeover. Organizers implemented a new structure for the workshops to create more meaningful change for the region so that the issues of water scarcity, air pollution, environmental degradation, and more can be addressed more effectively. All the workshops were interactive and cochaired by a chemist and an entrepreneur to promote new ideas and pave the way for new startups. The Middle Eastern participants presented their research in a guided poster session, which preceded the workshops. The topics included medicinal chemistry;

Zafra Lerman

Zafra Lerman is the President of the Malta Conferences Foundation, which has been using science as a bridge to peace in the Middle East since 2001 by initiating cross-border collaborations on issues including environment, water, science education, chemistry and nuclear security, energy, and climate change.

Prof. Lerman holds a BS.c. and MS.c in chemistry from the Technion and Ph.D. from the Weizmann Institute of Science. She conducted research on isotope effects at Cornell and Northwestern Universities in the US, and the ETH, Switzerland. She founded and was head of the Science Institute at Columbia College Chicago where she developed an innovative approach of teaching science using art, music, dance, and drama, which proved to be successful with underprivileged students around the globe.

From 1986-2011, she chaired the Committee on Scientific Freedom and Human Rights for ACS and is the vice-chair of the Board of the Committee of Concerned scientists, working tirelessly on human rights around the world.

She received over 40 international awards for her work, including the Presidential Award from President Clinton (1999); Royal Society of Chemistry, England, Education Award (2005); CRDF Global George Brown Award for International Scientific Cooperation (2007); AAAS Award for Science Diplomacy (2015); the Andrei Sakharov Award from the American Physical Society; the Peace and Justice Award from the UN NOVUS summit (2016); IUPAC Distinguished Women in Chemistry or Chemical Engineering Award (2017). She was honored three times by the US Congress with speeches about her work in 2002, 2004, and 2013.

biotechnology; nanoscience; chemical, biological, and nuclear security; energy and materials; and more.

Representatives from different funding agencies from around the world attended the workshops and discussed the possibility of financial support for several projects.

At Malta IX, efforts to include more women from the Middle East paid off: 35% of the participants were women, which is good for a science gathering in general and for the Middle East in particular. A special forum to promote women in science in the Middle East and encourage young girls to pursue careers in science was held every lunchtime throughout the conference. Diversity efforts during Malta IX also meant that the number of young people was especially high, as the American Chemical Society subsidized the cost of attendance at the conference for 15 young people from the Middle East.

The participants of Malta IX had an opportunity to network at events hosted by the Ministry for Foreign Affairs of Finland, the British High Commission in Malta, and the Malta Council for Science and Technology, which sponsored the closing ceremony at the Science Museum.

In his speech at the opening ceremony, George Vella, president of Malta, said: “It is heartening to see representatives from so many countries from the Middle East, including Nobel laureates, coming together to discuss ways forward and cooperation in science for the well-being of the people of the region and beyond.”

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Zafra Lerman
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and Emma Zajdela, a PhD student at
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A new analytical tool: Multiphoton electron extraction spectroscopy (MEES)

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1. Historical background

The ionization potential of most atoms and molecules is above 10 eV, so that their ionization, using UV light (3-5 eV per photon), should not be possible. Nevertheless, when using short laser pulses of high photon flux, nonlinear processes can take place, such that several photons can be simultaneously absorbed, resulting in ionization. Nonlinear laser multi-photon ionization (MPI) processes have been investigated for many years is physics and chemistry. In parallel to basic understanding of MPI processes and the associated effects, studies of their potential utilization for chemical analysis took place. Since almost all investigations of MPI processes were carried out under ultra-high vacuum conditions, the first analytical applications were in mass spectrometry. Later on, potential analytical applications of MPI under moderate pressure were suggested and, only recently, MPI at ambient conditions was introduced.

The MPI method is regarded as a well-established ionization technique in mass spectrometry, which leads to little molecular fragmentation [1]. This is an advantage for molecular identification. Therefore, it was used for ionization of large molecules [2] and was shown to be a very effective and sensitive technique [3]. Besides mass information, additional selectivity was achieved by tuning the excitation laser to the wavelength of resonant transitions [4-6]. Concerning analytical applications, the main drawback of this technology is that the signals are generated by accelerated masses under ultra-high vacuum conditions. It means that test samples must be introduced into the vacuum, where they are diluted. Laser ionization in mass spectrometry requires focusing the light beam to a small volume. Therefore, the number of generated ions is small, originating from only a small interaction volume. This is a considerable analytical drawback. Moreover, the setup, which included a mass spectrometer and a tunable laser, was very expensive; therefore, the method was never popular.

Another approach to utilizing MPI in analytical chemistry was based on measurements under moderate pressure (in the mTorr range). This improved the detection limits of vapors, simply because the number of analyte molecules in the interaction volume was much higher than in high-vacuum. A setup was developed in which not only was the pressure higher but also the interaction volume was increased by several orders of magnitude [7-9]. Obviously, because of the much shorter mean free path at these pressures, the detection could not be mass spectrometric but was based on the time-dependent voltages induced during the short flight of the ions. This method was tested for direct monitoring of ambient gases. It was sensitive, but not as good as mass spectrometry for molecular identification [10].

The third category of MPI analytical applications, introduced in the last decade, was based on detection of photoelectrons under ambient conditions. This method turned out to be a highly sensitive analytical tool for various substances in various forms and matrixes. It was applied to solids [11-16], liquids [17-18] and aerosols [19-23]. A pulsed UV laser

Dr. Valery Bulatov was born in1945 in USSR. He finished his PhD in 1979 in chemical physics at the Institute of Chemical Physics, Russian Academy of Science, Moscow. He immigrated to Israel in 1990 and joined the Technion. He serves as a senior researcher in the Faculty of Chemistry, Technion. He has published numerous papers in physical chemistry and analytical chemistry.

In 2015, he was awarded the Hershel Rich Technion Innovation Award. Currently, he is interested in development of spectroscopy-based methods for analytical chemistry and environmental chemistry, including laser-induced breakdown spectroscopy (LIBS), contaminated water analysis, soil contamination analysis, aerosols and hydrosols analysis, multiphoton electron extraction spectroscopy (MEES), historical artifacts, analysis and identification and investigation of hazardous and highly explosive materials.

beam ionized the substrate and the released charges were collected and counted. Since a single laser wavelength was applied, no molecular identification was possible and the only discrimination between the analyte and its substrate or matrix was based on differences in their ionization potentials.

The latest analytical development of multiphoton ionization was obtained at ambient conditions, using tunable OPO lasers. This is the multiphoton electron extraction spectroscopy (MEES) technology, which is the subject of this review. It is based on measurement of electrons emitted from samples irradiated by laser pulses, under a significant electrical field. The first studied samples included polycyclic aromatic hydrocarbons (PAH), explosives and materials of industrial interest. These studies resulted in the development of a new analytical spectroscopy, MEES, which is both extremely sensitive and informative.

2. What is multiphoton electron extraction spectroscopy (MEES)?

2.1 Multiphoton ionization

Multiphoton ionization is a process in which an electron is extracted from an atom or molecule using laser photons lower in energy than the ionization potential. In this process, several photons are absorbed by the species, which often does not obey the requirement of $h\nu = \Delta E$. Multiphoton ionization via virtual states can be theoretically described by k^{th}-order time-dependent perturbation theory, where k is the number of photons involved. The number of produced ions, dn, in a volume element dv and in a time interval dt, generated by a k^{th} order process is given by [7]:

$$\mathrm{d}n = n_0 G_k I^k \,\mathrm{d}v\mathrm{d}t, \qquad (1)$$

where n_0 in the concentration of neutral species, k is the number of the photons absorbed in the process, I is the laser photon flux ($cm^{-2}s^{-1}$), and G_k is the generalized cross section for the k^{th}-order process. For some lasers, the field intensity can be approximated as:

$$I(R,z,t) = I_M F(R,z)\, G(t), \qquad (2)$$

where I_M is a normalization factor depending on the total laser pulse energy, $F(R,z)$ is the spatial distribution (z is the beam direction coordinate and R is the radial coordinate) and $G(t)$ is the temporal distribution of the laser pulse.

Eq. (1) was developed for multiphoton ionization in the gas phase and the theory for surface ionization has not been developed yet. Nevertheless, probably a similar equation can be established for surfaces, where the volume element is replaced by an area element. Obviously, a new definition of the generalized ionization cross-section will be needed for surface ionization.

In principle, all possible ionization orders take place in parallel and contribute to electron extraction. In practice, the ionization probability drops with k and the dominant process is that of the lowest possible order. For many organic molecules, only two (or three) photons in the UV are needed to reach the ionization potential. Owing to the Gaussian profile of the laser beam intensity, not all molecules are exposed to the same flux, so that mixed ionization orders take place. This effect is much enhanced when the laser beam is focused.

In many cases, most of the photon energy is consumed in ionization and the released electrons are left with very little kinetic energy. Thus, they tend to recombine immediately with the ions. Therefore, extracting the electrons for analytical purposes requires application of an external high electric field for efficient collection of the photoelectrons.

2.2 The concept of MEES

Irradiation of many materials by UV laser pulses of high photon flux almost always results in a certain level of ionization, regardless of the laser wavelength. The ionization

Mr. Danny Fisher received his MSc in chemistry from Bar-Ilan University (under the supervision of Prof. A. A. Frimer), and now he is in the last stages of his PhD at the Faculty of Chemistry, Technion (under the supervision of Prof. I. Schechter). His PhD thesis is on the development and application of multiphoton electron extraction spectroscopy (MEES). Previously, he conducted multidisciplinary research related to trace explosives detection and the mechanism of particle adhesion and removal from surfaces. He was awarded the Teva award for excellent research in analytical chemistry (2016) and the Grushka Excellence Prize by the Israel Analytical Chemistry Society (2019).

caused by irradiation at an arbitrary wavelength is called "non-resonant ionization". It is a result of multiphoton excitation via virtual states of the molecule. Since these are forbidden transitions, the non-resonant ionization probability is very low. Thus, the background current from non-resonant ionization is also very low. However, when one of the photons (or a combination of photons) exactly fits the energy gap of a real molecular energy level, the transition is allowed, and its probability dramatically increases. This ionization is called "resonant ionization", since one of the photons (or a combination of them) are in resonance with a real energy state of the irradiated species. Therefore, the current observed at a wavelength corresponding to resonant ionization is much stronger.

The principle of MEES is that by scanning the laser wavelengths, one scans the various molecular energy levels and passes through many resonant transitions. These are detected via the increase in the photo-electron currents.

2.3 MEES instrument

The experimental setup is depicted schematically in Figure 1. A solid sample is placed on a stage and irradiated by the slightly focused beam of a pulsed laser. The sample is ionized in a multiphoton process. The photoelectrons are collected by a positive electrode placed nearby, at an electrical field of ca. 1000 Volt cm^{-1}. This produces a current, which is amplified and recorded as a function of time. The total photo-charges resulting from each laser pulse are calculated from the integration of the current over time. The laser wavelength is tuned in the UV range and the thus calculated photo-charges are recorded as a function of laser wavelength. MEES is the presentation of the photo-charges (often normalized by the laser pulse energy) as a function of laser wavelength [16].

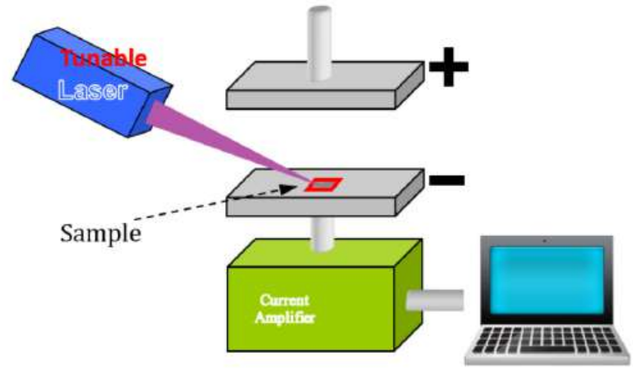

Figure 1. Schematic experimental MEES setup

3. MEES quantification and imaging

The ability of the MEES method to provide quantitative information has been shown in many cases. For example, the results for pyrene thin films of different surface concentrations are shown in Figure 2. In this case, quantification was based on the signal integrated over the range 230 – 240 nm (after baseline correction). The plot is linear over the whole range, and the results demonstrate the high sensitivity of the MEES method. Note the limit of detection of 160 fmol, which is one of the best in analytical spectroscopies.

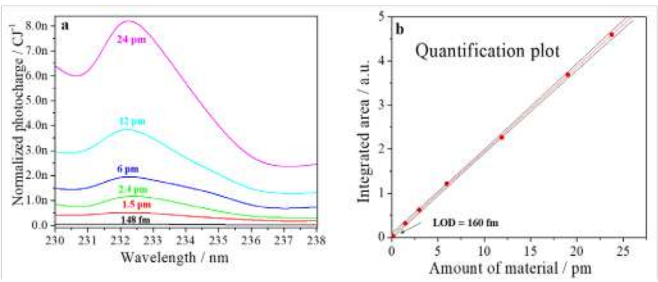

Figure 2. (a) MEES spectra obtained from different quantities of pyrene on the quartz surface. (b) Calibration plot for pyrene, based on signal integration over 230 – 240 nm range.

Dr. Vladimir V. Gridin was born in Leningrad, USSR, in 1954 and immigrated to Israel in 1973. He studied physics at the Technion, obtaining BSc, MSc, DSc degrees in 1978, 1983, 1987. His research was focused on low-temperature physics and laser physics of superlattices. He carried out postdoctoral research at McMaster University, Hamilton, Canada (1987-1990). He was nominated senior researcher at Witwatersrand University, Johannesburg, RSA (1990-1995; tenure since 1993). In 1995, he joined the Technion as a senior researcher at the Faculty of Chemistry. His current major research interests include laser physics, transport phenomena and superconductivity, physical chemistry, environmental physics and applications.

MEES surface imaging is feasible by scanning surface points, either by the laser mirrors or by using an X-Y stage for the sample [24]. The spatial resolution is determined by the mechanical setup but is limited by the optical diffraction limit. A too high resolution, close to the diffraction limit, may result in very low signals, since the laser power must be attenuated in order to prevent plasma generation.

An example of the imaging capabilities of MEES is shown in Figure 3. A droplet containing 30 ng of TNT was placed on a glass surface and the solvent was allowed to evaporate. The glass was scanned in the MEES setup [25].

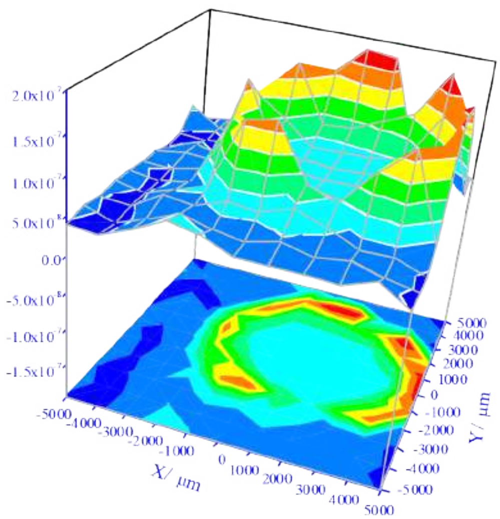

Figure 3. Scanning of a glass surface contaminated with 30 ng of TNT. Reproduced from Ref. [25] with permission of Elsevier.

4. Comparison of MEES to common optical spectroscopies

4.1 Methodology

Since MEES is a new optical analytical spectroscopy, its comparison to other well-established spectroscopies is of interest. The compared spectroscopies include the following [26]: (a) Direct absorption, (b) Reflection, (c) Fluorescence excitation and emission, (d) Micro-Raman, (e) Fourier-transform infrared (FTIR) and (f) Fourier-transform near infrared (FTNIR).

Obviously, the analytical performance of a spectroscopy depends on the analytes. One can find compounds that are well-handled by one method, while another method is not sensitive to them. Therefore, the comparison was carried out using such compounds that can be analyzed by all the spectroscopies. Polycyclic aromatic hydrocarbons (PAH) compounds possess strong fluorescence, high molar extinction coefficients and are Raman active. They are also MEES active. They dissolve in solvents and form thin films of well-defined surface concentrations. Five PAH compounds (anthracene, perylene, pyrene, coronene and chrysene) were selected.

Two morphologies were examined in this comparison: powders and thin films. Samples of all the materials at a series of well-defined surface concentrations were prepared and their spectra were measured by all the compared technologies.

4.2 Spectral characterization parameters

Visual inspection of the various spectra provides only a subjective impression of the analytical value of the compared methods, so quantitative parameters should be used. Several methods for evaluation of spectra have been suggested, but they are often misleading and not indicative of good analytical information [27-33]. Therefore, a new spectral characterization parameter was introduced.

The spectral characterization parameter is the spectral quality density (SQD), defined as $SQD = \frac{1}{\Delta\lambda}\sum_{i=1}^{M}\frac{p_i}{N}$ where p_i is the height of the i^{th} peak relative to its own surroundings, N is the noise level and M is the number of peaks. For each peak, p_i is measured from its own base, regardless of any wide spectral features on which it might be superimposed. $\Delta\lambda$ is the wavelength range of the measurement. The obvious

Dr. Shisong Tang was born in 1986. He studied chemistry and got his PhD from Northeastern University (NEU), China in 2016. He served as a researcher at Huazhong University of Science and Technology (HUST) from 2016-2019 and carried out research in laser spectroscopy. Now he is a postdoctoral researcher in Faculty of Chemistry, Technion. His main research topics are laser related technologies, including multiphoton electron extraction spectroscopy (MEES), laser-induced breakdown spectroscopy (LIBS), nanomaterials fabricated by lasers etc.

advantage of this parameter over the traditional signal-to-noise ratio is that it takes into account only the informative part of the peaks and is not affected by background or by wide spectral features that increase the peak height without adding significant information [26]. Since different spectroscopies are often measured in different wavelength ranges and extending the range artificially increases the spectral quality, the *SQD* is calculated per nm wavelength. This spectral characterization parameter well-represents human intuition of the analytical potential of a spectrum.

4.3 Comparison results

In the parametric comparison, the data was averaged over all the tested compounds. While comparing the spectroscopies for an individual compound might be accidentally biased, averaging over all compounds provides a more reliable comparison. The results are presented in Figure 4 [26].

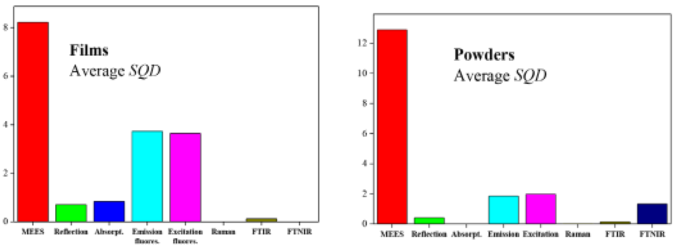

Figure 4: Spectral characteristics averaged over all tested compounds, for powders and for thin films. Reproduced from Ref. [26].

The results indicate that MEES is superior to all other tested spectroscopies, for all morphologies. This is because in multiphoton processes a small spectral range allows for sampling most of the energy levels of the molecule. The conclusions based on the *SQD* variable are also supported by the traditional limits of detection (LODs) obtained from calibration plots and based on 95% confidence intervals. For example, Table 1 presents the LODs obtained for thin films of pyrene.

Table 1. LODs of pyrene thin films obtained from calibration plots [26].

Spectroscopic method	LOD / pmol
MEES	0.16
Absorption	44
Reflection	2
Fluorescence	3
Raman, FTIR, FTNIR	> 1000

5. MEES applications

5.1 Application of MEES to explosive detection

One of the first applications of MEES was detection of explosives. The reason was that MEES signals from some chemical groups used in explosives are very high (a few orders of magnitude higher than many other compounds in the natural environment). These groups include nitro, nitrate, nitrite, nitroso, nitrate-ester, N-oxide, fulminate, NO radical, oxime, nitrosamine, furazan and isoxazole. Since sensitive detection of explosives on surfaces is of considerable importance, and due to the imaging capabilities of MEES, this technology is well-suited to this particular application.

Examples of spectra of two common solid explosives are provided in Figure 5. Clearly, the spectra of all explosive molecules possessing nitro/nitrate/nitroso-groups show similar features. At least 10 significant peaks are observed in the spectra of the nitro-based compounds in the examined laser-wavelength range. One group is close to 215 nm and another group is close to 226 nm. Note that the noise level in these measurements is very small and most of the observed spectral features are significant. It is of interest that it is possible to identify the specific explosive, based on the relative intensities of the 10 main characteristic peaks [25].

Prof. Israel Schechter holds the Abronson Family Academic Chair at the Technion. He did his PhD at the Hebrew University (1987) and joined the Technion in 1993. His current research interest includes development of new analytical chemistry technologies, laser spectroscopy, chemometry, and analysis of particulate matter. He has supervised ca. 40 MSc and PhD students and 25 post-doctoral and researchers. He published over 150 scientific papers. He serves as the President of the Israel Analytical Chemistry Society, as the Chairman of Israel Laboratory Accreditation Authority, and as the head of the chemistry program at GTIIT. He is the Editor-in-Chief of the journal Rev. Anal. Chem. and on the editorial board of 8 journals. Among his awards are: The Hershel Rich Innovation Award (1994, 1999, 2015), The Gutwirth Award for Excellent Research (1995), The Mitchell Entrepreneurial Award (1995, 2000), The Muriel and David Jacknow Award for Excellence in Teaching (2009) and The Israel Chemical Society Prize for Technological Innovation (2014).

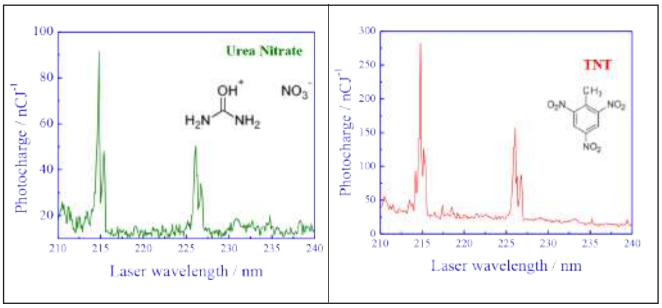

Figure 5. Multiphoton electron extraction spectra of explosives. Reproduced from Ref. [25] with permission of Elsevier.

5.1.1 Swab sampling of dust and explosives.

Security checks in most airports include collecting residues from suspected items using a swab, and transferring it to an explosives trace detector (ETD) based on ion-mobility spectroscopy (IMS). The swabs used in airports are optimized for collection of residues and for their introduction into IMS instruments. Although these swabs are not good sampling substrates for MEES, they were used in order to test MEES under common airport conditions. The swabs were used for sampling dust and some were spiked with TNT [25].

The MEES imaging of a typical spiked swab is shown in Figure 6 left. Scanning was performed at 226 nm, the frequency that indicates the presence of TNT. The MEES spectrum at a suspected spot is presented in Figure 6 right and compared to that collected on another spot. Although the swab itself and the dust cause many peaks, the characteristic signals of TNT at 215 and at 226 nm are clearly observed. These results suggested that MEES is a candidate for detecting trace explosives in airports.

Note that MEES directly detects explosives on the swab, while IMS technology requires heating the swab and testing the vapors. Therefore, when only a tiny explosive particulate is sampled, MEES might be more sensitive than IMS.

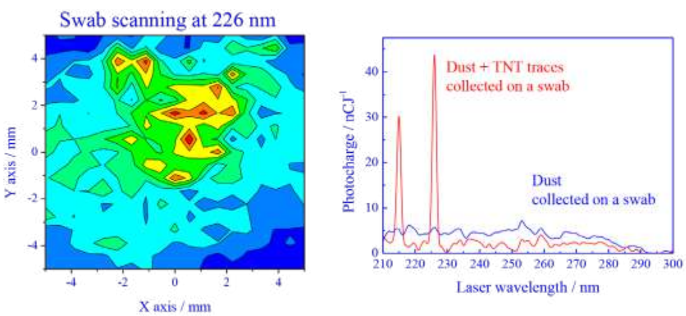

Figure 6. MEES imaging of a standard swab containing dust and spiked with TNT (left) and the spectra acquired at a suspected spot and at a non-suspected one (right). Reproduced from Ref. [25] with permission of Elsevier.

5.1.2 Forensic applications

MEES might also be useful in forensic applications. Here, the advantage of MEES is that it combines chemical and morphological information. For example, when explosives are found, there is the forensic question of identifying the involved people. Therefore, imaging MEES was applied for detection of explosives in human fingerprints. A surface was contaminated with TNT and a person was asked to touch it with a finger. Later, the finger was brought in contact with a glass slide, which was introduced into the MEES instrument and scanned at 226 nm. The results are shown in Figure 7. Clearly, the TNT traces along the fingerprint patterns can be observed. Unfortunately, the resolution of the X-Y scanner used and its range were not adequate for obtaining full fingerprinting. However, the results imply that a better spatial resolution and larger scanning area might allow for a combination of chemical identification (of explosives or drugs) and human fingerprint reading [25].

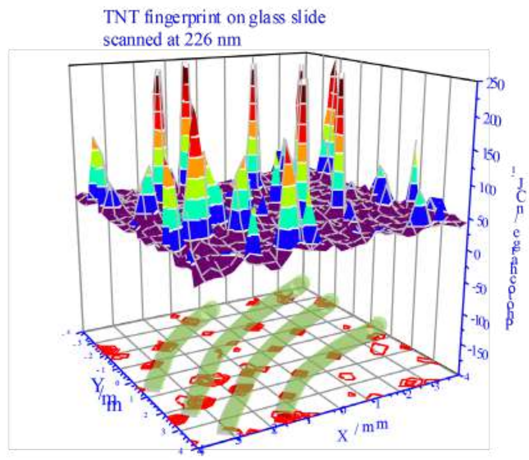

Figure 7. Mapping of TNT in human fingerprints on a glass slide using imaging MEES

5.2 Application of MEES to narcotic drugs

Another potential application of MEES is in identification and quantification of narcotic drugs. MEES is fast, very sensitive and can detect tiny amounts of solid material, without dissolution or any chemical preparations. MEES signals of drugs are unique and can be used for fingerprinting of these compounds.

Examples of MEES spectra of some important narcotic drugs are shown in Figure 8. These spectra indicate the fingerprinting capabilities of MEES. Traditional analysis of some of these compounds is difficult and time consuming. So far, no quantitative studies were carried out with narcotic drugs. Also, detection of drugs in complicated mixtures and matrixes have not been yet accomplished. Nevertheless, the highly featured MEES spectra imply their promising analytical potential.

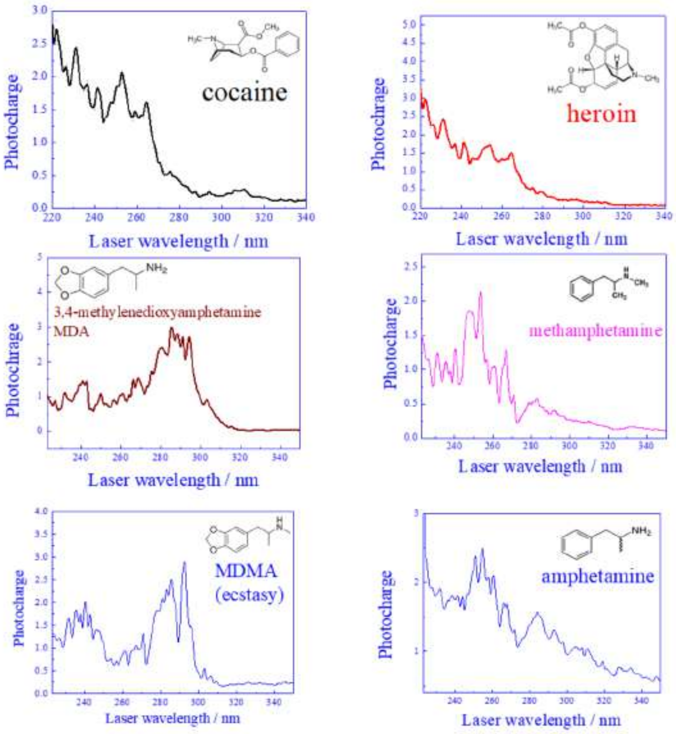

Figure 8. MEES spectra of some important narcotic drugs

5.3 Pharmaceutical applications

MEES spectra of several compounds of interest in the pharmaceutical industry have already been measured. These include methylphenidate (Ritalin) which is a psychostimulant drug, benzyl alcohol, which is a bacteriostatic preservative in medications and benzenesulfonic acid, which is needed (as salts) in the preparation of many pharmaceutical drugs. MEES spectra of these compounds are shown in Figure 9. However, for this case, no quantitative analysis has been carried out so far and matrix effects have not been investigated.

Figure 9. MEES spectra of compounds of interest in the pharmaceutical industry

5.4 Detector for chromatography

Many spectroscopies are used as detectors in chromatography, each of which is used when it provides an advantage over the other detectors. MEES could have an advantage due to its high sensitivity and potential selectivity, in its resonant mode. For example, if two compounds are hardly separated in chromatography, one can utilize differences in the resonant wavelengths to quantify both compounds [34].

The feasibility of applying MEES to inspection of developed TLC plates was exemplified for separation of 1-bromopyrene, benzo(e)pyrene and pyrene. Only partial resolution of the mixture took place. The plate was scanned along the evolution direction, using a laser wavelength of 355 nm (Figure 10). The fluorescence data are also presented for comparison. Clearly, the MEES imaging provides sharper peaks [34].

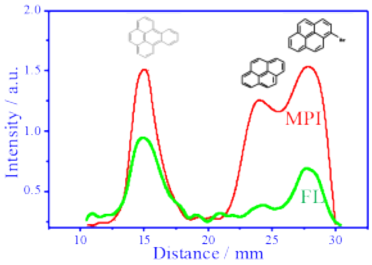

Figure 10. MPI and fluorescence scanning of a TLC plate, after partial development of a 1:1:1 mixture of benzo[e]pyrene, pyrene and 1-bromopyrene. Reproduced from Ref. [34] with permission of Elsevier.

MEES can also be used as a new HPLC detector. This was exemplified by comparing the peak of benzo(e)pyrene from HPLC separation obtained using UV absorbance detector, with the MEES results. The HPLC effluents were measured in a MEES setup at a resonant wavelength (see Figure 11). Clearly, the MEES data follow the UV absorbance data. The particular MEES setup used did not allow for continuous measurements; however, this engineering problem can easily be solved.

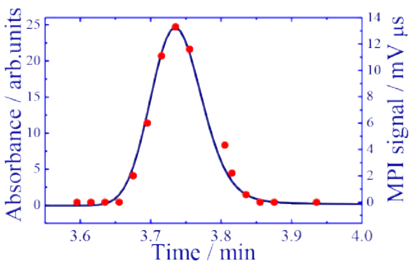

Figure 11. HPLC chromatogram (UV absorbance detector) of benzo(e) pyrene (solid curve) and resonant MEES of the eluates (dots)

5.6 Quantitative mapping of pesticides on plants

The application of MEES to detecting, quantifying and mapping of pesticide coverage on plants was demonstrated by analysis of imidacloprid, which is an effective pesticide. This compound is one of the reasons for the decline of the bee population in recent decades. Ensuring application of minimal pesticide quantity and preventing excess requires a fast method for monitoring the coverage on plants [36].

MEES spectra of imidacloprid on various plant surfaces, including olive and mint leaves (representing botanic leaves) and orange peel (representing fruit surfaces), were measured. (Figure 12). In all cases, the spectra included two distinct groups of peaks at 215 nm and 226 nm, independent of the surface.

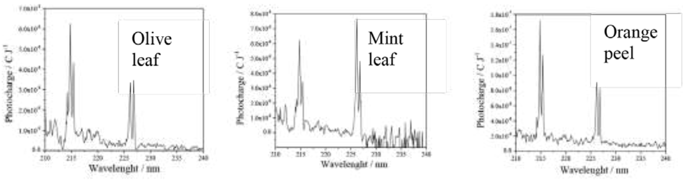

Figure 12. MEES of imidacloprid on olive leaf, mint leaf, and orange peel. Reproduced from Ref. [35] with permission of Elsevier.

MEES imaging of imidacloprid on olive leaves was also demonstrated in several morphologies. The spatial resolution was 500 µm. The results are shown in Figure 13. Clearly, MEES scanning can provide a map of this contaminant on botanical surfaces. The differences in peak intensities imply that quantification might also be feasible.

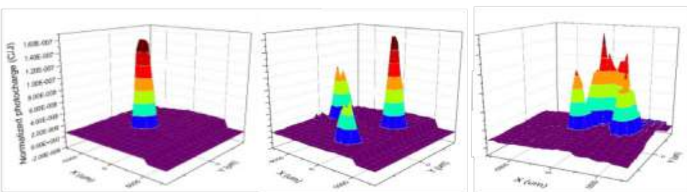

Figure 13. Examples of MEES imaging of imidacloprid on olive tree leaves at 215 nm. One dot (left), three dots (middle) and a U-shape contamination (right). Reproduced with permission from Ref. [35].

Quantification of the pesticide of the tested surfaces was based on the integral intensity over the imaging measurements. The LODs at 215 nm were 4.4 to 13.1 ng, depending on the surface. These values were low enough for such applications and the trueness and reproducibility values are acceptable for quantification. These findings indicated that MEES is a new method for fast detection and imaging of pesticides on plant material.

5.7 Analysis of aerosols

MEES spectra of aerosols from tobacco smoke collected on glass filters were measured and compared to the spectrum of normal room particulates (Figure 14). Tobacco smoke particulates exhibit intense peaks compared to the background. They are attributed to some benzene derivatives with a carbonyl substituted group. The results indicate that MEES can also be used for analysis of aerosols.

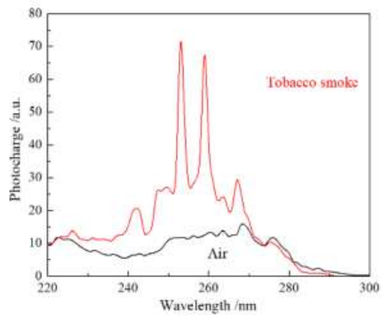

Figure 14. MEES spectra of tobacco smoke aerosols and of ambient air

6. Summary and conclusions

Multiphoton electron extraction spectroscopy (MEES) is a new analytical spectroscopy based on multiphoton ionization processes. Unlike traditional methods, MEES measurements are carried out under ambient conditions and the photoelectrons extracted in an electrical field are monitored, rather that the ions. MEES data is composed of the photo-charges generated in multiphoton ionization as a function of laser irradiation wavelength. MEES was compared to most common optical spectroscopies and was found to be more sensitive and informative for detection and quantification of materials.

Many experimental parameters were studied and optimized and an automated MEES spectrometer was constructed. This setup was tested for a variety of applications and was found to be a useful analytical tool. Among the most promising applications are sensitive detection of explosives, narcotic drugs and pharmaceutical compounds.

Many families of materials are MEES active, but definitely not all. In order to utilize this spectroscopy for identification of unknown samples, libraries of MEES spectra must first be compiled. So far, the MEES library consists of ca. only

200 molecules and materials. MEES can also be used for scanning a surface thereby providing chemical maps of specific compounds.

The first MEES instrument has just been developed and is not commercially available. Nevertheless, its performance under lab conditions was found to be superior to well-established commercial optical spectrometers. Clearly, there is place for further investigation and improvement of this technology.

Acknowledgments

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Terminology confusion in corrosion science and engineering

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Introduction

During my many years of teaching the subject of corrosion in universities and colleges, I came across astounding situations in which scientists and engineers referred to the same things by different names, or used wrongly or confused several designations and definitions in corrosion science and engineering. For example, they confused cathodic and anodic protection; passive and active protection; absolute, reversible, and stationary electrode potentials; standard and normal hydrogen electrodes.

Some people do not know whether there is any difference between stainless steel and "Nirosta"; between the chemical elements niobium (Nb) and columbium (Cb); between electrolytic, galvanic, voltaic, electrochemical, and corrosion cells. We can even meet such confusion in monographs, textbooks, and papers on corrosion.

We came across nine different terms that define the one *dealloying* phenomenon. Nobody seems to wonder how the use of such synonyms in language began. However, such situations in corrosion science and engineering may lead to confusion. Some terms are misleading: why do we refer to the dealloying phenomenon when iron leaches but carbon remains in the cast iron, as *graphitic corrosion* rather than as de*iron*ification? Is this only because scientists have agreed to use some terms that are historically wrong?

We enter into the labyrinth of terminology using terms such as *superalloys, high performance alloys, superaustenitic,* and *superduplex*. Try to find explanations for these words. All these terms and such questions, as well as ambiguity in terminology, brought me to think about clarifying this unfortunate situation in corrosion science and technology.

A recent event, which happened to one of my students, prompted me to write this paper. He reported at a conference organized by an oil company on the definition of efficiency of sacrificial Al-Zn ring bracelets for corrosion control of the outer surface of a submerged coated pipeline made from carbon steel, transporting crude oil in the Caspian Sea. Several engineers from the oil company urged the student to replace the term *cathodic protection* by *anodic protection*. The student was frustrated because he was taught that this instance was indeed cathodic protection. The problem of such engineers is that they "*do not know what they do not know*".

The aim of this work is to clear up the confusion. We invite you to participate in an attempt to sort out and resolve the

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His first book "*Corrosion for Everybody*" published by Springer in 2010 received the innovation award winner of Materials Performance Readers' choice in 2012 year in the USA. His second book "*Corrosion in Systems for Transportation and Storage of Petroleum Products and Biofuels*" was published by Springer in 2014. His third book "*Corrosion Problems and Solutions in Oil Refining and Petrochemical Industry*" was published by Springer in 2017.

He has special interests in the relationship between environment and corrosion phenomena, and the role of safety and human factor in corrosion management, corrosion education and in the searching of relationships between corrosion, art, history, and philosophy.

Dr. Alec Groysman is the Honorary President of the Israeli Association of Chemical Engineers and Chemists.

terminology confusion in corrosion science and engineering, which includes some important terms in electrochemistry.

1. Definition of the term *corrosion*

Each textbook on corrosion begins by defining corrosion. Most standards also begin from definitions, e.g. *Corrosion is the deterioration of a material, usually a metal, that results from a chemical or electrochemical reaction with its environment* [1]. In this definition, we will discuss only the term *material*. At the dawn of corrosion experiments, when the Anglo-Irish chemist Robert Boyle revealed in 1667 that metals dissolve in hydrochloric acid, he referred to this phenomenon as *corrodere*, which means "to eat away" in Latin [2]. This approach allows us also to talk about "corrosion" of non-metallic materials: polymers, ceramics, glasses, and composites [3]. Some engineers and scientists use the term "corrosion" only with respect to metals, and feel that it is better to refer to "destruction", "destroying", "degradation", "decomposition", "decay", "degeneration", "wear", or "deterioration" with regard to non-metallic materials. Nowadays, however, more and more specialists talk about the corrosion of non-metallic materials [3]. This is correct if we follow the above definition of corrosion.

We should emphasize that not all reactions of materials with the environment and not every deterioration of a material qualifies as "corrosion". Dissolution of sugar and salt in water, and burning of wood or paper clearly do not involve corrosion. However, oxidation of metals is corrosion, in particular electrochemical oxidation.

In all the definitions that we are aware of, corrosion is regarded as a nasty undesired phenomenon. However, there are many constructive beneficial corrosion phenomena like corrosion of sacrificial anodes in cathodic protection, corrosion of one element in electric batteries, anodizing, passivation, etc. We can name at least twenty such beneficial corrosion processes [2]. In my opinion, the most correct definition of corrosion is thus *the physicochemical interaction of a material with the environment resulting in <u>changes</u> of properties of both the material and the environment*. This definition is very close to that given in ISO 8044 [4] where the word *deterioration* is replaced by *changes*.

2. Examples of confusion and misunderstanding in corrosion science and engineering

2.1 Electrode potentials

We have read about different terms for *electrode potential* on a metal surface: *absolute, electric, electrostatic, reversible, equilibrium*, *standard*, *irreversible*, *normal*, *stationary*, *corrosion*, *electrode*, *mixed*, *rest*, and *open-circuit*. Are they different? Are there synonyms among these 14 names? We shall begin with the *absolute* and *reversible* potentials.

2.1.1 Reversible potential

If pure iron is immersed in 1M $FeCl_2$ solution, an electric double layer is formed on the iron surface. In this layer, a potential difference between the metal and the solution is formed at a single interphase. The simplest model is represented by a parallel plate condenser (a capacitor) with an *absolute electric (electrostatic) potential* E_a, which cannot be calculated or measured (Fig. 1). The following *reversible* redox reaction takes place on the iron surface:

$$Fe^{2+}_{(aq)} + 2e^{-} \leftrightarrow Fe_{(s)}. \qquad (1)$$

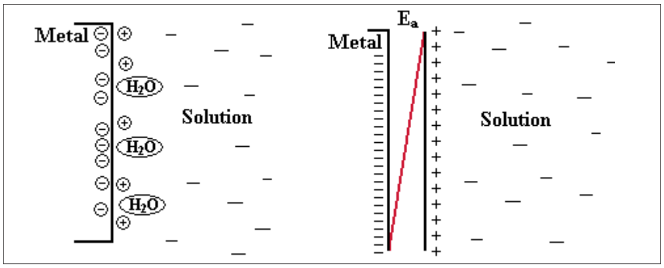


Figure 1. Electric double layer (capacitor) formed at the metal surface in aqueous electrolyte solution. ⊖ - electrons. ⊕ – metallic cations. Ea – absolute electric potential [2].

The *reversible* electrode potential corresponding to the redox reaction (1) is set on an iron surface immersed in 1M $FeCl_2$ solution. It represents the equilibrium of only one material and is also called *equilibrium potential*. The *reversible* electrode potential is defined by activity of species in (1) occurring on the metal surface. The state of equilibrium at a constant temperature is defined only by the nature of a metal and activity of cations of the same metal in a solution. A *reversible* potential E is defined by the Nernst equation:

$$E = E^{o} + \left(\frac{RT}{nF}\right)\ln a_{M^{z+}}, \qquad (2)$$

where E^o is the *standard reversible* potential at $a_{M^{z+}} = 1$; $a_{M^{z+}}$ is the activity of M^{z+} cations in solution; in this case, $M^{z+} = Fe^{2+}$. Therefore, the *reversible* (*equilibrium*) potential of a metal does not depend on the dimensions of the electrode or on the volume of the solution, and remains constant with time. If a *reversible* potential on a metal surface is measured in relation to the standard hydrogen electrode, the *reversible* potential is termed E^o, the *standard electrode potential*; the old name *normal electrode potential* is now obsolete.

2.1.2 Corrosion potential

If we put the same piece of pure iron in aerated potable water, two different reactions that define the corrosion process take place on the iron surface:

anodic: $$Fe_{(s)} \rightarrow Fe^{2+}_{(aq)} + 2e^-, \quad (3)$$

cathodic: $$O_{2(aq)} + 2\,H_2O_{(l)} + 4e^- \rightarrow 4\,OH^-_{(aq)}. \quad (4)$$

An electric potential value is formed on the iron surface when these two reactions take place simultaneously. This potential is called *irreversible*, *corrosion*, *electrode*, or *stationary potential* ($E_s = E_{corr}$). Polarization curves (see Fig. 2) help us to understand the appearance of the *corrosion* potential, and the German scientists C. Wagner and W. Traud were the first to explain this in 1938, naming it a *mixed potential* [5]. Some scientists called it a *rest potential*.

The *corrosion potential* can be measured in two ways. The first is based on measuring the *corrosion* potential in relation to some reference electrode when there is no net electrical current flowing through the metal surface. This is *corrosion potential* at an open electrical circuit, or OCP (*open-circuit potential)*, or *zero-current potential*. Thus, the *corrosion potential* is the potential of a corroding surface in an electrolyte measured under open-circuit conditions relative to a reference electrode. Otherwise, *corrosion potential* is the potential difference between an electrode of a given metal, immersed in an electrolyte, and a reference electrode, when the current flowing to and from the metal electrode is zero. The second way of measuring the *corrosion potential* is based on polarization curves (see Fig. 2). It is also called *electrochemical corrosion potential,* or *free corrosion potential* [1]. Thus, we have eight synonyms for the *corrosion potential*. Certainly, for any novice, this situation may be complicated and confusing.

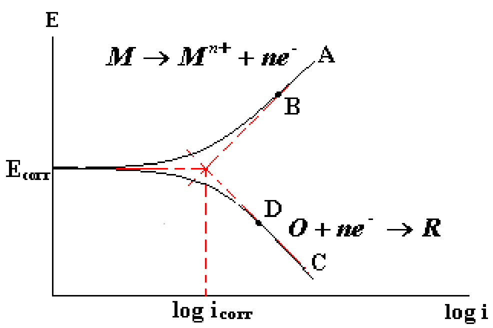


Figure 2. Polarization curves for the corrosion process M + O → M^{n+} + R, where M is a metal, O is an oxidizer (O_2, H_3O^+, Fe^{3+}), and R is a reduced species [2].

2.2 Standard hydrogen electrode (SHE) and normal hydrogen electrode (NHE)

The reversible hydrogen electrode operating under standard conditions (T = 298.15 K, pH = 0, and $f_{H_2(g)}$ = 1 atm.; f – fugitivity) was chosen as a commonly accepted reference electrode, and its potential was assigned an arbitrary value of zero: E^o = 0.000 V [6]. It was conventionally accepted also that E^o = 0.000 V at any temperature. The standard hydrogen electrode (SHE) is based on the electrochemical redox reversible reaction (5):

$$2H^+_{(aq)} + 2e^- \leftrightarrow H_{2(g)}. \quad (5)$$

One should note the difference between the SHE and the normal hydrogen electrode (NHE). The former implies that a_{H^+} = 1M and E^o = 0.000 V, while the latter implies that C_{H+} = 1M and $E^o \approx$ 0.000 V [6]. The SHE is called a *primary* or *basic* reference electrode that consists of a platinized sheet or a wire immersed in 1M HCl solution with H_2 gas bubbled through it at 1 atm. Half of the platinum electrode should be in the solution, and the other half should be above the solution in the H_2 gas stream (see Fig. 3). Unfortunately, usually the platinum electrode is shown as if it is fully immersed in the solution.

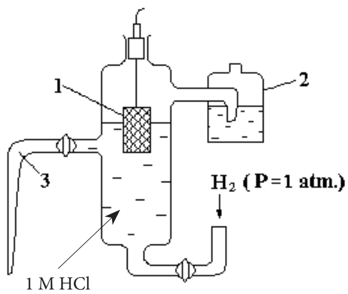


Figure 3. The normal hydrogen reference electrode (NHE) [2]. 1 – Platinum; 2 – Water plug; 3 – Electrolytic key. Inside the vessel: 1M HCl – hydrochloric acid at a concentration of 1 mol/liter.

3. "Neutral" or "normal" pH?

Sometimes authors write "normal" pH when they have in mind the neutral pH of 7. There is, of course, no such thing as a "normal" pH. We should use only "neutral" when referring to pH = 7.

4. Corrosion mechanism

The corrosion mechanism is the way in which deterioration of a metal occurs. In spite of so many metals and alloys and media types around them, we differentiate two types of corrosion mechanisms: in the absence of electrolytes (no influence of electrical potential and current), and in the presence of electrolytes (influence of both electrical potential and current) [2]. This is similar to dry corrosion and wet corrosion, or chemical and electrochemical mechanisms. Which terms are correct? Probably, all three pairs are justified.

5. Stainless steel = "Nirosta"?

Stainless steels are iron-base alloys that contain at least 10.5% Cr [7]. We may read in other sources [8], a "minimum of 11% Cr". Sometimes, it is added "and a maximum of 1.2% carbon" [9]. We may also read that "true stainless steels are ferrous alloys (>50% Fe), with sufficient chromium additions to give the characteristic *passivity*" [7]. Thus, we should explain what *passivity* is. "Passivity is the state to be *passive*" [1]. And probing further: "*Passive* is the state of a metal surface characterized by low corrosion rates in a potential region that is strongly oxidizing for the metal" [1]. Furthermore, we continue to go deeper and deeper depending on our knowledge and understanding of all words and expressions in the previous definition. For instance, we reveal two undefined expressions: *low corrosion rates* and *strongly oxidizing*. And so on …

The history of invention and creation (we even find "discovery" [10]) of stainless steel is full of incredible stories and disputes. In 1922, the trademark Nirosta, the abbreviation of "NIcht ROstender STAhl" (*nonrusting steel* in German) by ThyssenKrupp, came into life [10]. This was austenitic 18Cr-8Ni stainless steel (UNS 30400). Even in an authoritative source [10], we can read "*Nirosta stainless* steel", one word immediately following a similar one (a tautology). Now we understand that Nirosta is the German for stainless steel. Unfortunately, even a stainless steel is not always "stainless". Stainless steel is thus an oxymoron (like *original copy* or *clearly confused*) in that it can stain, corrode and rust under extreme atmospheric or contaminated environments. If people do not know under which conditions stainless steel is truly "stainless", this can lead to catastrophic circumstances. Pitting corrosion, stress corrosion cracking (SCC), and microbiologically induced corrosion (MIC) – all these phenomena can occur with stainless steels (Fig. 4).

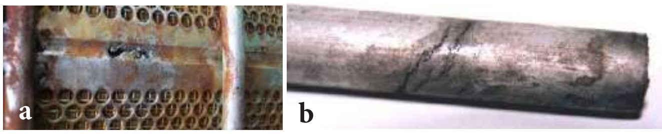


Figure 4. Corrosion of stainless steel: a – pits in SS 316L in sea water, b – chloride stress corrosion cracking of SS 316 tube in an atmosphere that contains HCl gas, and c – MIC attack of SS 304 after three months of contact with tap water containing iron bacteria (stagnation).

6. Definition of stainless steel by applying a magnet

Do engineers correctly identify stainless steel, observing that the magnet is not attracted to the steel surface and conclude that "*this steel is stainless because it is nonmagnetic*"? But … there are five types of stainless steels according to crystallographic structure: ferritic, martensitic, austenitic, duplex, and precipitation hardening (PH). Only austenitic stainless steel that has not been work hardened is nonmagnetic. Other types of stainless steel are magnetic. Therefore, the use of a magnet can be applied only to decide if the steel is austenitic and cannot be used to define ferritic, martensitic, duplex, and PH stainless steels. Nowadays, there are about 270 types of stainless steels. In general, we should write in plural (stainless steels) and not in singular (stainless steel).

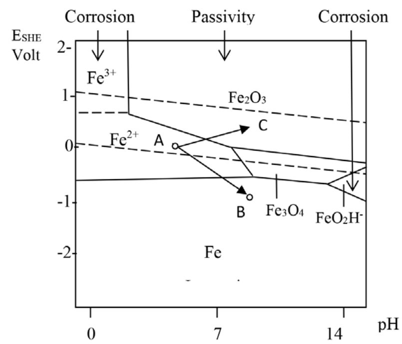
7. Passive protection and active protection

Sometimes in textbooks on corrosion, one can read that "*cathodic protection may be active and passive*". And then – passive protection relates to sacrificial anodes. This is wrong. Passive protection applies to coatings. Active protection applies to cathodic protection by means of either sacrificial anodes or impressed current.

8. Cathodic protection and anodic protection

In spite of the clear distinction among these two fundamentally different protection methods (cathodic and anodic) that are well described in the literature, some engineers and educators confuse them. *Cathodic protection* is the turning of protective metallic construction from anode to cathode, which does not corrode, by shifting the electric potential to the negative area. *Anodic protection* is the turning of the protective metallic construction to a passive state by a shift of the electric potential to positive values (see Fig. 5); it is a metastable state, namely a very delicate condition that is based on the existence of a passive protective tenacious film on the metal surface. This means that any changes in the external conditions (potential, temperature, agitation, stresses) can lead to disturbance of this state, such that corrosion will occur.

Figure 5. Potential *vs.* pH (Pourbaix) diagram for Fe-H_2O at 25 °C. A → B – cathodic protection, A → C – anodic protection.



9. “Stray current” and “leakage current”

An external current is one of the key factors in environment aggressiveness, and can result in severe *electrocorrosion* [11]. It is possible to divide the external current into *a stray current* and a *leakage current*. The *stray current* is the current flowing through paths other than the intended circuit [1]. The fact that in many cases these paths are unknown served as a basis to designate this type of current by the term *stray current* [11]. At the moment when the current leaks off from the current source or from some metallic parts connected directly to this current source, it is most convenient to designate it as a *leakage current*. For example, such a term is suitable for the current flowing down from the rails and facilities of electric traction systems (Fig. 6).

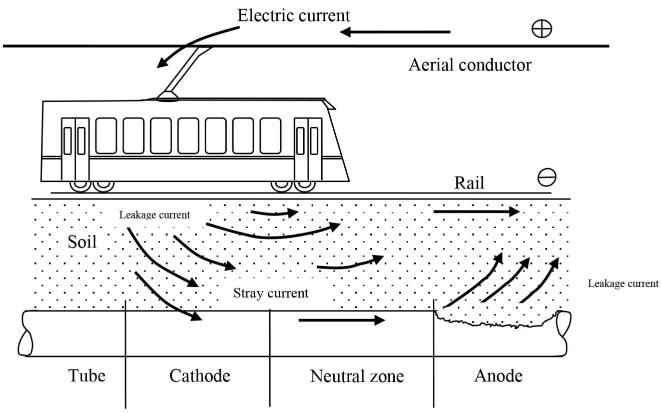


Figure 6. Stray *vs*. leakage currents.

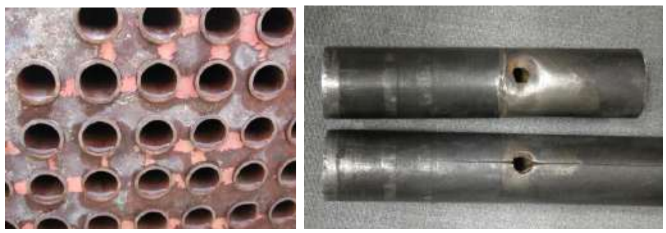
Spreading in the ground, currents create electric fields that may be nearby or sometimes remote, several kilometers from their sources. That is why they have been named *stray currents*, reflecting the arbitrary character of their distribution over great distances. Other similar terms – “vagrant” and “vagabond” currents that were in use in the first period when this phenomenon was revealed did not survive [12]. The term “interference” current is often used in the case of stray current attack of cathodically protected structures where stray currents interfere with protection currents [11].

The attack by stray currents is often called “*stray current electrolysis*” or even “*electrolytic corrosion*”. The use of the term “electrolysis” [13] is ambiguous but this name is also correct, as in the electrolysis process, the external current alone (leakage current) drives metal atoms into the electrolyte as water-soluble ions. The environmental factors (oxygen, chlorides, pH) that are so critical to spontaneous corrosion processes are not relevant. The extent of damage or loss of metal is directly proportional to the magnitude of leakage current at the point of discharge. Stray current corrosion is usually localized where the leakage current leaves the metal structure and enters the electrolyte (soil, water or concrete, see Fig. 7).

Figure 7. Examples of stray current corrosion. Left picture courtesy of IKA Laboratories Ltd.

10. Dealloying

Dealloying is a corrosion process whereby one constituent of an alloy is preferentially removed, leaving an altered residual structure (Fig. 8) [1]. In the literature, one can find other names for dealloying: *dealloying attack, parting corrosion, parting, selective dissolution, selective leaching, selective corrosion, preferential leaching*, or simply *leaching*. One phenomenon with nine names!



a b

Figure 8. Examples of dealloying: a – dezincification; b – decarbonization (decarburization).

11. Columbium (Cb) and Niobium (Nb). What is the difference? Niobium and Columbium in stainless steel

We should elucidate the use of two names for the same chemical element: niobium (Nb) and columbium (Cb) [10, 14]. In chemistry, it is widespread that one substance or element has two or more names (synonyms). For instance, tungsten and wolfram (W), hydrochloric acid and muriatic acid (HCl), ammonia and hydrogen (or trihydrogen) nitride (NH_3), water and dihydrogen monoxide (H_2O), sodium carbonate and soda ash, or washing soda (Na_2CO_3).

The British chemist Charles Hatchett discovered over two centuries ago (in 1801) a new element in a mineral sample named columbite, which was sent from the United States, and named it columbium (Cb) after Columbia, the poetical name for America [10, 15]. Several decades later, in 1844–1846, the German chemist Heinrich Rose rediscovered this new element in the columbite ore and named it niobium (Nb) for the goddess Niobe, a daughter of the king Tantalus in the Greek mythology. Thus, during an entire century, "columbium" was used in America, while "niobium" was employed in Europe. To end this confusion, the name niobium was adopted in 1950 by IUPAC, the International Union of Pure and Applied Chemistry [16]. Some metallurgists, metal societies, and commercial producers in the US still use the name columbium instead of niobium … but it is well known these two names refer to the same chemical element.

12. What is the cause of corrosion?

Corrosion is caused by thermodynamic instability of metals. Even if the metals were 100% pure, they would corrode in most media due to the negative Gibbs energy change, $\Delta G < 0$, for these oxidizing reactions. The heterogeneity of metals influences the corrosion kinetics. The Swiss scientist Auguste-Arthur De la Rive was probably the first to observe, in the 1830s, that zinc dissolved faster when it contained impurities. Thus, he suggested a hypothesis about electrochemical reactions between zinc and impurities contained within it [2]. Alas, the reason for corrosion of metals is their thermodynamic instability, rather than their heterogeneity.

13. Electrolytic, galvanic, voltaic, electrochemical, and corrosion cells: Differences and similarities

An *electrolytic cell* (Fig. 9) resembles a cell with spontaneous corrosion, but there are essential differences. The main determinative distinction is the presence of an external source of direct electrical current (DC). Each electrode in the cell, regardless of the nature of the metal, can serve as an anode or a cathode, depending on the pole of the electric source to which it is connected. The polarity of the electrodes is opposite to the polarity in a conventional corrosion cell: the *anode* (corroding electrode) has a *positive* polarity, while the *cathode* is *negatively* charged.

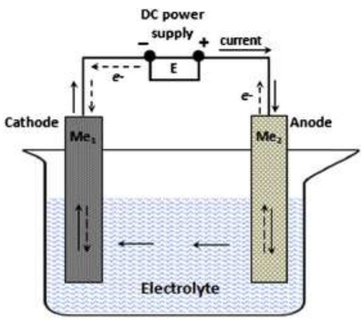


Figure 9. Electrolytic cell [11]. DC – direct current. Me_1 and Me_2 – different metals.

In corrosion, *galvanic* = *voltaic* = *electrochemical* = *corrosion* cell are synonyms for an electrochemical cell that uses spontaneous redox reactions to generate electricity. In the Daniell electrochemical cell and in the use of sacrificial anodes in cathodic protection, corrosion is a constructive phenomenon. Unfortunately, in most corrosion processes, energy dissipates, and metal is also lost (Fig. 10).

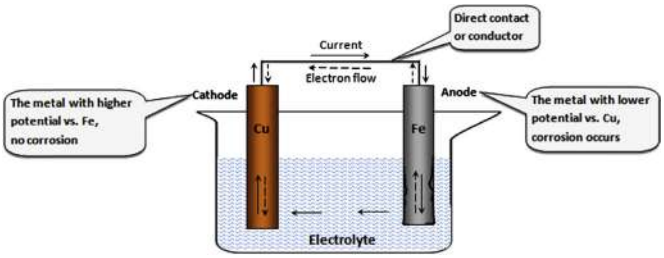


Figure 10. Galvanic = Voltaic = Electrochemical = Corrosion cell [11].

14. Galvanic corrosion and other synonyms in corrosion science and engineering

When writing my first book titled "Corrosion for Everybody" (Springer, 2010), I sent several chapters to the famous corrosion scientist A.V. Shreider. He read them and wrote a letter with several notes. One of them was "I am not familiar with *dissimilar metal corrosion*". I answered him that this are two other names for *galvanic corrosion* – *contact corrosion* or *two different metal corrosion*. One phenomenon but has four synonymous names; linguistics is truly a complicated science…

We are familiar with other synonyms in corrosion science and engineering:

- decarbonization = decarburization (see Fig. 8).
- intergranular corrosion = intercrystalline corrosion.

Here are some other synonyms for the same phenomenon or process:

- Stress corrosion cracking (SCC) = environmentally induced cracking = environmentally assisted cracking.
- Galvanic plating = electroplating = electrogalvanizing = electrodeposition = electrolytic coating.
- Mechanically assisted degradation = velocity phenomena = erosion–corrosion = flow-assisted corrosion = flow-accelerated corrosion = flow-induced corrosion = cavitation-erosion = liquid-impingement erosion.
- Impingement attack = impingement corrosion.
- Metal spraying = "Schoop process" = flame spraying = thermal spraying = metalizing. The Swiss engineer Max Ulrich Schoop (from Zurich) invented the first flame-spraying "gun" for metallization in 1913 [2].

15. Hydrogen damage, attack, or corrosion

Hydrogen atoms can penetrate into metals and impact their structure. When hydrogen is the cause of damage, we come across so many names that it feels as if we are in the depths of a forest with an abundance of different plants. We estimate that there are 14 names related to hydrogen damage (Figs. 11 and 12). Destruction occurs under stresses which can be both static and cyclic. The latter case is called *hydrogen fatigue*. The different terms for hydrogen damage are listed below:

- Hydrogen-induced cracking (HIC) = hydrogen-assisted cracking (HAC) = hydrogen cracking (HC) = hydrogen embrittlement.
- Hydrogen blistering (HB) = stepwise cracking (SWC).
- Stress-oriented hydrogen-induced cracking (SOHIC).
- Sulphide stress cracking (SSC).

Hydrogen damages occur in the presence of tensile stress, which may be residual or applied (SOHIC and SSC), or internal stress resulting from the interior pressure of hydrogen gas (hydrogen blistering and HIC).

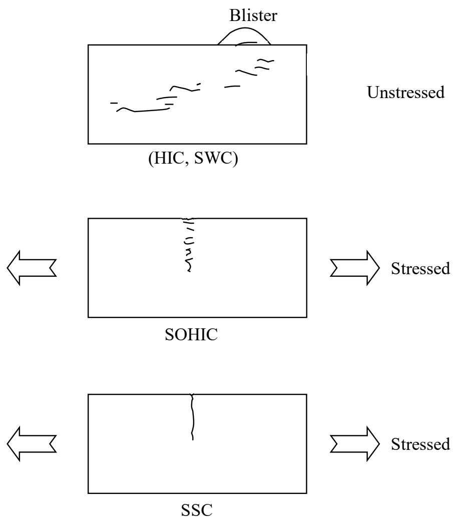
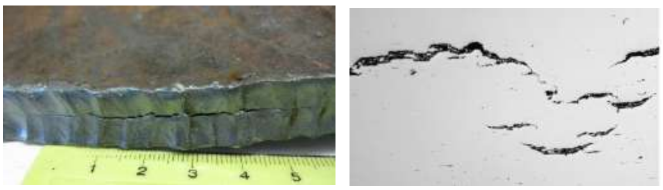


Figure 11. Typical hydrogen damages in metals and alloys [2].



a b

Figure 12. Hydrogen damage: a – cross-section through a shell of a heat exchanger with cracking, and b – metallographic cross-section (×60) through the shell wall of the heat exchanger with delamination, showing hydrogen embrittlement, or HIC or SWS [14].

16. Rust – what is it?

Our knowledge about corrosion begins with rust. Ask any layman "What is corrosion?", and as a rule his answer will be "Oh, that is rust". What do we know about rust?
Rust is a corrosion product forming *only* on iron and carbon steel surface. It is incorrect to say "white rust" for corrosion products of aluminum or zinc, or "blue rust" or "green rust" for corrosion products of copper. We should instead refer to "corrosion products" of aluminum, zinc, or copper. Rust is an orange-red-reddish-brown color resembling the color of iron oxide, Fe_2O_3, named *hematite* (Fig. 13). This is the main source of iron production for the steel industry. It is widely used as a pigment in paints and cosmetic, and in medicine as calamine lotion to treat mild itchiness [17]. Cave paintings dating back to 40,000 years ago were created with *hematite* pigments. There are 16 known iron oxides and oxyhydroxides (Table 1) [18]. There are five polymorphs of FeOOH and four polymorphs of Fe_2O_3.

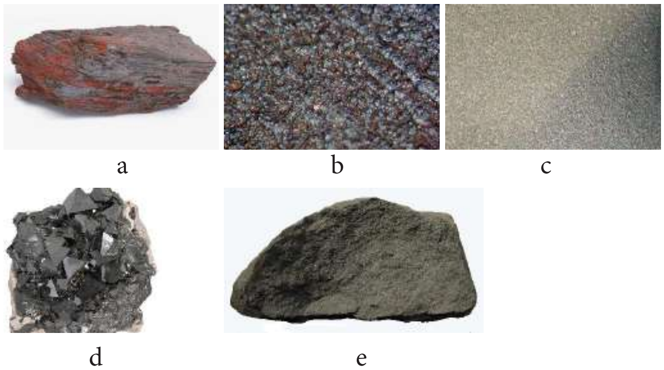


Figure 13. a - Hematite (iron ore) [19]. b – Wüstite [20]. c – Magnetite formed on carbon steel surface after passivation. d – Magnetite [21]. e – Maghemite [22].

Table 1. Iron oxides and oxyhydroxides [18].

Oxide-hydroxide or hydroxide		Color	Density, g/cm^3
α-FeOOH	Goethite [1]	Yellow-brown	4.26
γ-FeOOH	Lepidocrocite [2]	Orange	4.09
β-FeOOH	Akaganéite [3]	Yellow-brown	3.52
δ-FeOOH			
δ`-FeOOH	Feroxyhyte	Red-brown	4.20
FeOOH	High pressure		
$Fe(OH)_3$	Bernalite	Red-brown	3.32
$Fe(OH)_2$		White-bluish	
$Fe_5HO_8 \cdot 4H_2O$	Ferrihydrite	Reddish-brown	3.8

$Fe_x^{III}Fe_y^{II}(OH)_{3x+2y-z}(A^-)_z$; $A^-=Cl^-$; $½SO_4^{2-}$	Green Rust		
$Fe_{16}O_{16}(OH)_y(SO_4)_z \cdot nH_2O$	Schwertmannite	Yellow-brown	≈3.8

Oxide		Color	Density, g/cm³
α-Fe_2O_3	Hematite	Red	5.26
Fe_3O_4	Magnetite	Black	5.18
γ -Fe_2O_3	Maghemite	Reddish-brown	4.87
β-Fe_2O_3			
ε-Fe_2O_3			
FeO	Wüstite	Black	5.90-5.99

[1] *Goethite* is one of the most thermodynamically stable iron hydroxides at ambient temperature. It was named in 1815 in honor of a German poet Johann Wolfgang von Goethe, who was also a scientist and the Minister for Mines for the Duke of Weimar [18].

[2] *Lepidocrocite* is named after its platy crystal shape (lepidos means scale in Latin) and its orange color (krokus is Latin for saffron).

[3] *Akaganéite* – γ-FeOOH – was named after the Akagané mine in Japan where it was first discovered in 1961 [18].

The first recorded use of *rust* as the name of a color in English was in 1692 [23], as the name of the iron corrosion phenomenon of iron oxidation. The word *rust* found its etymological origins in the Proto-Germanic word *rusta*, which translates to *redness*. The word is closely related to the term *ruddy*, which also refers to a *reddish* coloring in an object [24]. By the way, the red color of rust is like the color of our blood. Poetically, this means that "*rust is a blood of deteriorated, corroded iron*". We should take into consideration that in addition to hydroxides and oxides, rust can also contain different ions (e.g., Cl^-, SO_4^{2-}, CO_3^{2-}, Ca^{2+}, Mg^{2+}), dust, dirt, soot, fats, oil, and sand [2]. Corrosion products of iron can be of different colors (Table 2) [2].

Table 2. Colors of corrosion products of iron [2].

Corrosion product	*Chemical Name*	*Color*
$Fe(OH)_2$	Iron (II) hydroxide	Blue-green
$Fe(OH)_3$ or FeOOH or $Fe_2O_3 \cdot nH_2O$	Iron (III) hydroxide	Red – brick-brown
FeO	Iron (II) oxide, Ferrous oxide, Maghemite	Gray-black
Fe_2O_3	Iron (III) oxide, Ferric oxide, Haematite	Orange-red
Fe_3O_4	Iron (II, III) oxide, Magnetite	Black-grey
FeS	Iron (II) sulfide (troilite), $Fe_{1-x}S$ (pyrrhotite), $Fe_{1+x}S$ (mackinawite)	Black
Fe_2S_3	Iron (III) sulfide	
FeS_2	Iron disulfide, Pyrite	
$FePO_4$	Ferric phosphate	Yellow – Brown
$Fe_3(PO_4)_2$	Ferrous phosphate	Brown
$FeCO_3$	Ferrous carbonate, Siderite	
$FeSiO_3$	Ferrous silicate	Black
$Fe_2(SiO_3)_3$	Ferric silicate	
$Fe(NO_3)_2 \cdot H_2O$	Ferrous nitrate hydrate	Green
$FeSO_4 \cdot 7H_2O$	Ferrous sulfate hydrate	
$FeBr_2 \cdot 6H_2O$	Ferrous bromide hydrate	
$(NH_4)_2Fe(SO_4)_2 \cdot 6H_2O$	Ferrous ammonium sulfate hexa- hydrate, Salt of Mohr	

Some people see a definite aesthetic value in different rust colors and forms and even organize exhibitions of rusted articles (Fig. 14) [25]. Indeed, one can see different colors, lines and forms, including veins in stress and "blood" of iron.

Figure 14. Rusted pier, Tel Aviv, the Mediterranean Sea, Exhibition "The Swan Song" 2014 [25]. Photograph by Yoram Reshef and Rafi Peled.

17. Precipitation-hardening or age-hardening materials

Some metallurgists call the fifth category (according to structure) of stainless steels *precipitation-hardening* (heat treated) or *age-hardening* materials. However, this is actually a process, rather than a distinct family of materials. Heat treatment is carried out to increase yield strength; it can be applied to several materials, most of which do not fall into the stainless steel category: certain aluminum or nickel alloys, and *maraging* (martensitic + aging) steel. The most common martensitic precipitation-hardening (PH) stainless steel grade is 17-4PH (UNS 17400 or AISI 630) [26]. UNS – Unified Numbering System. AISI – American Iron and Steel Institute.

18. Superalloys, high performance alloys, superaustenitic, superduplex

When I first came across these various terms, it was surprising, as the word "*super*" belongs to a qualitative terminology, rather than technical and scientific language. It felt as if somebody had marketed new alloys by means of words used in the definition of common goods.

The prefix "*super*" comes from the Latin word *super* which means "above, over, beyond" [27]. It was first used in the 1680s as a prefix in "superfine goods" denoting that the goods are of the highest grade. It began to be used to mean "first rate or excellent" in 1837, and its extended usage as a general term of approval started in 1895. It declined for some time during the early and mid-1900s, and was revived in 1967.

Then, I revealed that even the very big company Outocumpu put the combination "*high performance stainless steel"* under the title of the company [28]. I approached some companies producing *high performance or super alloys* with requests to elucidate these terms. Only one of them answered: *this term "high performance alloys" is normally used to describe nickel- or cobalt-base alloys that offer performance beyond that of stainless steels. They may be superalloys, corrosion- or heat-resistant alloys or high strength alloys. Properties of interest are strength, creep resistance, heat or corrosion resistance and physical properties (e.g. expansion)* [29]. You are hereby invited to delve into the description and discussion of these various terms.

18.1 Corrosion resistant alloys (CRAs)

Corrosion resistant alloy (CRA) is a rather subjective term. CRAs are alloys that achieve a high degree of corrosion resistance through alloying. They cover a wide range of materials from stainless steels (UNS S42000 – 13Cr) to nickel-base (UNS N10276 – C276) and titanium alloys that tend to form passive films [30–32]. In some conditions, all stainless steels are CRAs, whereas in others they undergo different corrosion phenomena (see Fig. 4). These materials can reduce corrosion rates in producing environments to less than 0.025 mm/year without the use of inhibitors or other mitigation techniques.

The term *corrosion resistant alloy* is commonly used to cover all *alloys that are to some degree capable of resisting corrosion compared with carbon steel* [33]. This resistivity to corrosion is not universal because it depends on the specific corrosion environment and the alloying composition of the given alloy. CRAs vary considerably from each other. Therefore, we come across different definitions of CRA.

According to both the NACE (National Association of Corrosion Engineers) and EFC (European Federation of Corrosion), "*CRA is an alloy intended to be resistant to general and localized corrosion of oilfield environments that are corrosive to carbon steel*" [34]. Or "*alloys whose mass-loss rate is at least an order of magnitude less than that of carbon and low-alloy steel, thus providing an alternative method to using inhibition for corrosion control*" [35].

According to the American Petroleum Institute (API), "*CRAs are non-ferrous materials in which any combination of titanium, nickel, cobalt, chromium or molybdenum comprises at least half of the material by mass*" [36, 37]. In another API document [38], one can read that "*CRA intended to be resistant to general and localized corrosion and/or environmental cracking in environments that are corrosive to carbon and low-alloy steels.*" Thus, most sources compare CRA with only carbon steel. These alloys are ideal to cope with the aggressive environments found in wells that are sour from hydrogen sulfide, carbon dioxide, and other chemicals.

To summarize, following analysis of the different definitions of CRA, it is probably better to use the term *corrosion appropriate alloy*, which means that it is suitable for this particular environment.

18.2 High performance stainless steels

These steels were developed for use in highly demanding environments and have high Cr, Ni and Mo content. Many are also alloyed with nitrogen to further increase corrosion resistance and mechanical strength. Some of the steels are alloyed with copper to increase the resistance to certain acids. High performance stainless steels have high resistance to uniform, pitting, crevice and SCC [38].

18.3 Superaustenitic steels

Pitting resistance equivalent number (PRE or PREN) is used to rank different stainless steels by their ability to withstand chloride-induced pitting corrosion, taking into account the effect of the most important alloying elements (6).

$$\text{PREN} = \%\text{Cr} + 3.3\,(\%\text{Mo} + 0.5 \times \%\text{W}) + 16 \times \%\text{N} \tag{6}$$

The greater the PREN, the higher the resistance of the alloy to pitting corrosion. Superaustenitic stainless steels are defined as austenitic, iron-based alloys that have PREN > 40 [39].

These alloys can be used in seawater [40, 41]. For comparison, PREN = 25 for SS 316L.

Superaustenitic is defined as an austenitic grade in which the non-ferrous elements exceed 50%. As such they are not considered stainless steels. This means that a "moly 6" grade such as 254 SMO (UNS S31254) counts as a stainless steel, whereas other "moly 6" grades (e.g. 904L UNS N08904) do not. Nevertheless, alloy 254 SMO is sometimes termed superaustenitic. Alloy 654 SMO (22% Ni and 7.3% Mo) is a "moly 7" superaustenitic designed for severe corrosion service in the offshore oil and gas industry [26].

18.4. What is the difference between a nickel alloy and a superalloy?

A nickel alloy (or nickel-based alloy) is an alloy in which nickel is the chief alloying element by mass. In many such alloys, nickel makes up over half the material. They are typically used in severe corrosive conditions, especially at high temperatures, in the oil and gas, chemical and petrochemical industries, and in the turbines of power stations and jet engines. They are typically known by their trademarks, for instance Hastelloy, Inconel, Waspaloy, or René. Some of these are also termed "superalloys" or "high-performance alloys" because of their high corrosion resistance or ability to withstand the extreme thermal conditions of modern gas turbines and jet or rocket engines. Apart from nickel, other materials can constitute the chief alloying element of superalloys including cobalt and titanium [26].

18.5 What is the difference between lean duplex, normal duplex, super duplex and hyper duplex?

Alloys with PREN > 40 are considered *super duplex*; e.g. SAF 2507 SD (PREN = 42.5). A grade is called *hyper duplex* if its PREN ≥ 48; e.g. SAF 2707 HD and 3207 HD (PREN = 48 and 50, respectively). The lower-alloyed, less corrosive resistant duplex grades, e.g. LDX 2101 (UNS S32101) and 2304 (UNS S32304) are considered *lean*. Conveniently, duplex grades are often designated by a four-digit number that indicates the chromium percentage in its first two digits and the nickel percentage in its last two digits. Thus, lean duplex grade 2304 contains 23% Cr and 4% Ni [26].

19. Crude oil and fuels

In the terminology of crude oil and fuels, confusion also exists. It is important to elucidate the main terms. The word 'petroleum' means rock oil from the Latin *petra* (rock or stone) and *oleum* (oil). Therefore, 'crude oil', or simply 'crude', are synonyms of 'petroleum' [14]. The word 'petrol' was first used in reference to 'refined petroleum' in 1892. It was previously used to refer to 'unrefined petroleum'. This is the first source of confusion. We shall now elucidate how different fuels are named in various countries. This can be confusing for any traveler.

Gasoline. Gasoline is an English word that refers to the fuel used for automobiles. The Oxford English dictionary dates its first recorded usage as 1863 [42]. The term 'gasoline' was first used in North America in 1864–1865. The word is derived from the word 'gas' and the chemical suffixes -ol and -ine or -ene [42]. The shortened form 'gas' for 'gasoline' was first recorded in American English in 1905 and is often confused with the older word 'gas' (from Greek *chaos*) that was used by the medieval alchemist Paracelsus in the early 1600s. In the US (United States), gasoline is called 'gas', but in the UK (United Kingdom) it is known as 'petrol'. When people from Europe visiting the US for the first time hear 'gas station', they do not understand right away that this is a 'gasoline station'.

In some languages, the name for 'gasoline' is *benzin* in German, *benzine* in French, бензин in Russian (adopted from the French *benzine*), and *benzina* in Italian. In Argentine, Uruguay and Paraguay you may hear the word *nafta* instead of gasoline. The word *benzin* was formed from the Latin word *benzoe*, which came from the Arabian *lubān ğāwi* or *lubān jâvî* that means 'javanese incense'. *The* Arabian *lubān* is close to the Hebrew *lebōnā* that means '*incense*' [43]. This scent gave the term *benzoe* because chemists believe that the aroma of a rose depends on the volatile benzoic oil contained in its flowers. And then French *benzine* arose from it. Really, gasoline has strong specific pungent almost sweet smell, and probably some people like it. The term *benzin* was introduced by the German chemist Eilhard Mitscherlich in 1833 for the designation of the benzoic acid derivative. *Benzene* is the compound responsible for gasoline's gassy smell [44]. Benzene has a naturally sweet scent to which most noses are particularly sensitive. It is so pungent that the human nose can already detect 1 ppm in the air that is inhaled. Throughout the 1800s and early 1900s, benzene was added to after-shaves and douches to give these products a sweet aroma. It was also used as a solvent to decaffeinate coffee. But these uses did not last long, and for good reason: *benzene* is a known carcinogen and is dangerous when inhaled in high concentrations or upon long-term exposure [44]. *Benzene* may be present as an aromatic component in crude oil or can be added (not more than 1 wt%!) to gasoline to increase the octane number, thereby improving engine performance and fuel efficiency.

Kerosene (paraffin, paraffin oil, coal oil). The Canadian geologist Abraham Gesner in 1846 produced a clear liquid in distillation of coal tar and oil shale. He showed that this liquid was lamp fuel, and the name *kerosene* was given by him, as a contraction of the Greek word *keroselaion* meaning *wax-oil*. However, Abraham Gesner was not the first; the Persian alchemist Abū Bakr Muhammad ibn Zakariyyā al-Rāzī (854-

925 CE) described in the 9th century two methods for the production of *kerosene*, termed *white naphtha*. Why was *kerosene* also called *paraffin oil*? In 1848, the Scottish chemist James Young performed dry distillation of resinous coal and produced a liquid, which he named *paraffin oil*, because it congealed at low temperatures into a substance resembling paraffin wax. *Wax* refers to a class of chemical compounds that are plastic (malleable) at ambient temperatures. Wax candles and sculptures at the Madame Tussaud museum are typical examples. In the history of kerosene production, we should also mention the American Samuel Martin Kier (1813–1874) who was the founder of the American petroleum refining industry, and the Polish pharmacist Jan Józef Ignacy Łukasiewicz (1822–1882) residing in Lvov who in 1856 built what was probably the first oil refinery in the world. Samuel Martin Kier distilled kerosene from crude oil by a process of his own invention in 1851 and sold it with the newly invented lamp for burning kerosene to local miners under the name *carbon oil*. Ignacy Łukasiewicz distilled kerosene from local seep oil, invented the modern kerosene lamp (working with success at a local hospital), built the first street lamp in Europe, and constructed the first oil well in Poland. Crude oil became the major source of kerosene after 1859, when Edwin Laurentine Drake (1819–1880) drilled the first oil well in the US state of Pennsylvania.

Kerosene is mainly used nowadays as a fuel for jet engines in aircraft and some rocket engines (therefore, *kerosene* is called *jet fuel* in aircraft), for cooking, burning in lamps and domestic heaters or furnaces, as a solvent for greases, as a lubricant, as an effective insecticide, and in entertainment for fire performances, such as fire breathing, fire juggling or poi, and fire dancing.

In Israel, historically laymen refer to 'kerosene' (that is used in heaters) as 'neft', and all Israelis know that this is not crude oil but the fraction after distillation, which is used for heating. In Iran, you may hear 'naft', in Poland – 'nafta', in Switzerland – 'petrol' or 'petroleum', but all these names mean 'kerosene' [45]. In England, we may hear 'paraffin' or 'lamp oil' instead of 'kerosene'. Therefore, we should be careful when travelling from one country to another.

In my childhood in Yalta, Crimea, in the 1950–1960s, kerosene was used for cooking and lighting. Cooking was done in portable stoves, called Primus invented in 1892 by Frans Wilhelm Lindqvist, a factory mechanic from Stockholm [46]. I liked reading under a kerosene lamp. A joke was prevalent in my native town of Yalta: once a fortnight, two barrels containing kerosene on horse-drawn cart were brought to our street, and the man who sold this kerosene went near the horse and called out "kerosene!" When teachers asked a small child at a school "How does a horse scream?" the child answered "kerosene!".

Naphtha. The origin of the word *naphtha* is unclear [47]. Akkadian clay tablets from about 2200 BC referred to crude oil as '*naptu*' from which derives the root of the Arabic '*naft*' as well as the Greek '*naphtha*', the Hebrew '*nepht*', the old Persian '*naptic*' *or* '*nafata*', and the modern Farsi '*neft*' [48]. They were all used to describe bubbling oil [47]. *Naphtha* may also derive from the name of the Vedic Hindu god Apam *Napat*, the god of freshwater, sometimes described as a fire-god [47]. The word *naphtha* was used to refer to any sort of crude oil or pitch; it refers to a miraculous flammable liquid in the Old Testament [49]. '*Water-white naphtha*' was first used in Islamic medicine for fighting disease and infection.

Naphtha is used primarily as feedstock for producing high-octane gasoline (called reformate), in the bitumen mining industry as a diluent, in the petrochemical industry for producing polyethylene and polypropylene, as a solvent for cleaning applications, and as a fuel in camp stoves.

Conclusion and insight into the future

We analyzed the terminology confusion that currently exists in corrosion science and engineering. Clarification concerning misunderstandings of electrode potentials, hydrogen electrode, and corrosion cells applied in electrochemistry were also provided. We revealed synonyms for a single material or phenomenon. It was shown that a comprehensive definition of any phenomenon or object rarely exists. This is a quite frequent situation in science and engineering. For example, attempts undertaken to unify designations of alloys beginning in the 1970s (UNS – unified numbering system) did not lead to the desired results. One can find the last inventions with proprietary designations of stainless steels by the Outocumpu Company [28] and Haynes International [50].

Certainly, it is impossible to encompass in one paper all issues concerning the terminology confusion in corrosion science and engineering. Thus, acidic cleaning (named also chemical descaling or pickling), three kinds of polyurethane material (flexible, rigid, and coating), and many types of Viton and Teflon need careful analysis and clarification.

The corrosion community (NACE International and EFC) should organize a commission similar to IUPAC, in order to consider terminology and definitions in corrosion science and engineering and thus clarify the current confusion.

Acknowledgments

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Jonas Salk (1914-1995) and the first vaccine against polio

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Abstract

Dr. Jonas Salk developed the first vaccine against polio. When asked who owns the patent on the vaccine, Salk answered: "Well, the people, I would say. There is no patent. Could you patent the sun?" [J. S. Smith, *Patenting the Sun,* William Morrow, New York, 1990.]

The Salk vaccine induces immunity from an inactivated or killed-virus. Salk: "I perceived the situation this way: since successful killed-virus vaccines had not yet been developed, it was simply assumed that it couldn't be done. As we now know, it can be done, but in order to determine why it had not yet been done, it was necessary to think about it first, to construct hypotheses and theories that then guided the experimental research." [P. Weintraub, ed., *The Omni Interviews*, Ticknor & Fields, NY, 1984.]

Inactivated vaccine

Jonas Salk: "The first moment that a question occurred to me that did influence my future career, occurred in my second year at medical school… we were told in one lecture that it was possible to immunize against diphtheria and tetanus (bacterial infections) by the use of chemically treated toxins, or toxoids. And the following lecture, we were told that for immunization against a virus disease, you have to experience the infection, and that you could not induce immunity with the so-called 'killed' or inactivated, chemically treated virus preparation. Well, somehow, that struck me. What struck me was that both statements couldn't be true. And I asked why this was so, and the answer that was given was in a sense, 'because.' There was no satisfactory answer. It was in a sense a paradox. It didn't make sense and that question persisted in my mind.

I had an opportunity to spend time in elective periods in my last year in medical school, in a laboratory that was involved in studies on influenza. The influenza virus had just been discovered about a few years before that. And I saw the opportunity at that time to test the question as to whether we could destroy the virus infectivity and still immunize. And so, by carefully designed experiments, we found it was possible to do so.

That was how that particular line of investigation occurred, and it influenced my career. I interrupted those studies because I graduated from medical school and interned. The war broke out, influenza was important, and I continued on in research in that field, developed a flu vaccine, and that led to all sorts of other things…

The principle that I tried to establish was really that it was not necessary to run the risk of infection, which would have been the case if one were to try to develop an attenuated or weakened polio virus vaccine. And so it seemed to me the safer and more certain way to proceed." [1]

Bob Weintraub was born in Brooklyn, New York and made aliyah in 1975 to Beer Sheva, where he remained. He earned the PhD in Physical Chemistry from MIT and the Diploma in Library Science from the Hebrew University of Jerusalem. He held positions in scientific and technical librarianship in industry, hospital and academic institutions. He is now retired. He has an interest in the history of chemistry.

Jonas Salk

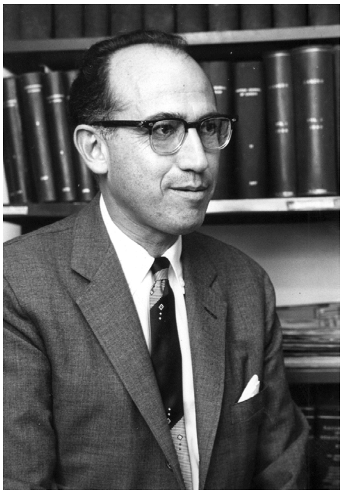

Figure 1. Jonas Salk. Photograph D. Harris/Hebrew University of Jerusalem.

Jonas Salk (Figure 1) was born in 1914 to Russian Jewish immigrant parents in New York City, where he grew up. He earned his undergraduate degree from the College of the City of New York in 1934 and his medical degree in 1939 from New York University. He took a break from his medical studies to accept a one-year research assistantship on protein chemistry. He worked with streptococcus bacterium under the supervision of Dr. R. Keith Cannan. In his senior year, he carried out two months of elective work on viruses under the supervision of Dr. Thomas Francis, Jr. From 1940-42 Salk served as an intern at the Mt. Sinai Hospital in New York City. With the outbreak of the war, Salk joined Dr. Francis, then at the University of Michigan, in his work on the influenza vaccine. Influenza was of vital military importance – in Europe during the First World War more American soldiers died from influenza than were killed in combat. In 1947, Salk accepted a position at the Virus Research Laboratory of the University of Pittsburgh School of Medicine, located at Municipal Hospital. In the 1960's he established the Salk Institute for Biological Studies [2-6].

Salk, discussing how antisemitism affected his career: "In some instances, anti-semitism played a role. I always realized that that was always a factor. In fact, I almost did not get into medical school because of quotas at that time. So, I was prepared for other eventualities. I was already prepared to go to graduate school to study endocrinology, for example, if I had not gone into medical school. It becomes necessary to be prepared for alternative paths. There may be a greater opportunity when something is denied." [1]

Poliomyelitis

Poliomyelitis, from the Greek, polio (grey) and myelon (marrow, indicating the spinal cord), is a virus-borne disease that enters the body through the mouth and is spread primarily by fecal matter. Polio had been endemic with mostly mild infections occurring in infancy, when paralysis is rare, leaving the infant with lifetime immunity. About 95% of the individuals with poliomyelitis infections experience no symptoms at all. Infected asymptomatic persons shed virus in the stool and can infect others. Another estimated 4 to 8% of the infections last less than a week with complete recovery with symptoms that are not distinguished from other viral illnesses. A further 1-2% of people infected experience symptoms of non-paralytic aseptic meningitis (stiffness of neck, back, and/or legs) for 2-10 days and recover completely. Fewer than 1% of the infections result in flaccid paralysis. Many persons with paralytic poliomyelitis recover completely and in most muscle function returns to some degree. Weakness or paralysis still present 12 months after onset is usually permanent. The death-to-case ratio for paralytic polio is 2-5 % (depending on age) for children and 15-30 % for adults. In the 19% of cases with bulbar involvement, the death-to-case ratio increases to 25-75%. There is no cure for the disease once an individual has become infected.

Increasing outbreaks of polio and epidemics of growing magnitude, from the middle of the 19th through the middle of the 20th century, coincided with rising levels of hygiene. The disease could now strike older individuals more susceptible to paralysis, who as a result of better hygiene, had not been exposed to the virus as infants. Infants have some protection against the disease by maternal antibodies transmitted through the placenta and by breast feeding [7].

Vaccine

It was known by 1948 that poliovirus exists in at least three types. Immunity to one type does not provide immunity to the other types: type I is the most common paralytic type; type II the milder, often asymptomatic type; and type III, the often lethal type that paralyzes breathing. Work on a vaccine required knowing whether additional strains existed, as a successful vaccine would provide immunity to all of them. In 1948 Salk and three other laboratories accepted a grant from the *National Foundation for Infantile Paralysis* (supported by the fundraising campaign known as the *March of Dimes*) to conduct a three-year polio virus typing study. The work involved injecting monkeys with known and unknown strains and then checking the immune responses. The four laboratories used 17,500 monkeys. The study found that the 196 strains tested all belonged to one of the three known types.

Salk was interested in finding an inactivated vaccine. He had experience with this from his influenza work, where together with Francis, he had developed a formalin-killed vaccine effective against influenza virus. Salk: “The principle that I tried to establish was really that it was not necessary to run the risk of infection, which would have been the case if one were to try to develop an attenuated or weakened polio virus vaccine. And so it seemed to me the safer and more certain way to proceed. That if we could inactivate the virus, that we could move on to a vaccine very quickly. Whereas if you were dealing with weakened virus, you would have to demonstrate its safety eventually. So that was the reason and there was a principle that was involved. You might say a scientific principle, a fundamental principle: choosing and preferring that which the safety – which you could control, and the qualities which you could use. So that this is, in a way, a more scientific approach. Trying to work like nature, instead of imitating nature.” [1]

Drs. John F. Enders, Thomas H. Weller, and Frederick C. Robbins at Harvard University were awarded the 1954 Nobel Prize for Medicine or Physiology for their discovery that poliomyelitis viruses can grow outside the body in cultures of various types of non-nervous-system tissue. They succeeded in growing polio virus in human embryonic tissue derived from skin, muscle, and intestines. This breakthrough eliminated two major obstacles in poliovirus research: It allowed the growth and harvesting for experimental purposes of unlimited quantities of poliovirus– previous to their work, laboratories were dependent on infected spinal cords of monkeys to grow the virus; and it permitted work to go ahead on a vaccine without having to use nervous tissue which was known to cause dangerous allergic reactions when injected into human bodies.

Salk seized upon this discovery and started tissue-culture studies of polioviruses.

Salk: "The work that he (Enders) has done stands out in the last years as one of the most outstanding contributions in poliomyelitis research. It has been possible, simply by following Dr. Enders' technique, but using monkey testes as a somewhat more available tissue, to isolate virus quite readily from human stool suspensions…Using monkey testes it has been possible also to grow virus readily… The value of this tissue – and I am sure that there will be many others that will be discovered in time – has made it possible to extend immunologic investigations rather broadly. We have been able to prepare from the testes of a single monkey two hundred tubes which, for immunologic studies, would correspond to two hundred monkeys, using the same number of tubes as one would use animals." [2]

Salk investigated the chemical reaction between the viruses and formaldehyde. This was the key to inactivating the viruses so that they were noninfectious but could still activate the body's immune response. He found it best to combine tissue-cultured virus and formalin in proportions of 1:250 at 1°C for periods from 7 to 21 days. Salk also learned to grow the viruses at a very fast rate by using monkey-kidney tissue rather than monkey-testes tissue and by using a commercial synthetic tissue-culture nutrient known as Medium 199. By 1952 Salk was able to report that in monkeys the virus killed by formalin did not cause paralysis and provided a lasting immune response. The next step was human trials.

In 1952, Salk carried out experiments of his vaccine at two Pennsylvania institutions on 161 children with the consent of their parents or guardians. At both institutions Salk first took blood samples and typed them. At the Watson School the children were victims of polio or suffered from other crippling conditions, i.e., congenital crippling conditions. At the Polk School for the mentally disabled, some children had antibodies for one or more types and some did not. Salk first inoculated the children who were polio victims with vaccine of the same virus type that he found in their blood in order to measure the antibody response. He then vaccinated children who were not polio victims and thus did not have polio antibodies in their bodies to protect them from any remaining live virus that might be present in the inactivated vaccine. Salk: "When you inoculate children with a polio vaccine, you don't sleep well for two or three weeks." [8] No child contracted polio and no side effects were observed.

Blood samples taken from those vaccinated were placed into tissue cultures containing virulent poliovirus. The antibody produced by the vaccination killed the virus. "It was the thrill of my life. Compared to the feeling that I got seeing those results under the microscope, everything that followed was anticlimactic." [3] The experiments showed that the vaccine raised antibody levels that lasted for months and that the vaccine was safe.

Salk admitted later that he first tested the vaccine on himself and other members of his laboratory. Around this time he inoculated his wife and three sons. Salk: "I look upon it as ritual and symbolic. You wouldn't do unto others that which you wouldn't do unto yourself." [9]

After further trials on about 15,000 children, in 1954 under the supervision of Dr. Thomas Francis, *The National Foundation for Infantile Paralysis* sponsored a massive clinical trial of the "Salk vaccine." In the United States, 650,000 schoolchildren were injected with either vaccine or placebo and 1.2 million others were observed controls that did not receive any injections. In 1955, Dr. Francis reported that the vaccine was 60 to 70% effective in preventing infection with type 1 poliovirus, the most prevalent strain, and at

Figure 2: Jonas Salk at the award ceremony of the Honorary Doctorate from Hebrew University of Jerusalem. 10 May 1959. [11] Photograph Shlesinger/Hebrew University of Jerusalem.

least 90% effective against types 2 and 3. Today almost 100% immunity is achieved after three doses. The Salk vaccine was approved for use in the United States within two hours of the announcement of the results of the trial. In 1959, Dr. Salk received an honorary doctorate from the Hebrew University of Jerusalem (Figure 2).

Dr. Albert Sabin of the University of Cincinnati Medical School by 1957 had developed another polio vaccine. His vaccine was made of live attenuated polioviruses and is administered orally.

The use worldwide of both the Salk and Sabin vaccines has brought poliomyelitis to the brink of eradication. Kathleen Murray was Jonas Salk's assistant for the last five years of his life. After giving a tour to teenagers at the Salk Institute, she reported back to Dr. Salk in disbelief that she had met people who have never heard of polio. "Ah," responded Dr. Salk, "Isn't that just what we want?" [10]

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P. Weintraub referenced in the abstract is the author's cousin.

History of electron microscopy for materials at the Weizmann Institute

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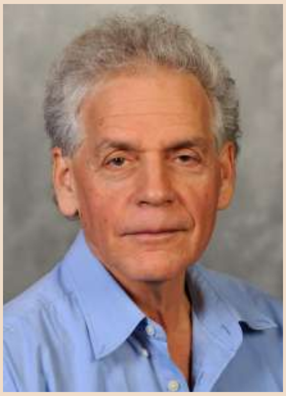
Following three years as a postdoc in Battelle Geneva, I joined the Department of Plastics Research of the Weizmann Insitute (WIS) as a researcher in the summer of 1979. My research was funded by a Minerva (Germany) grant given to the photoelectrochemistry group in this department. This group, consisting of Prof. Joost Manassen z"l, Dr. David Cahen (from the Structural Chemistry Department) and Dr. Gary Hodes, had already made a name for itself in the mid-seventies by pioneering research on solar energy conversion using photoelectrochemical cells, based on cadmium sulfide and cadmium selenide electrodes immersed in polysulfide electrolyte. Figure 1a shows one of the group meetings *circa* 1981 in the seminar room/library of the department in the basement of the Levine building (used now for genomic research). The Levine building and the two huts at the rear of the building, which hosted the department, were somewhat remote and isolated from the main Faculty of Chemistry premises, i.e. the Perlman and Bergman buildings. The research conditions were far from ideal, to say the least. However, the department staff was scientifically motivated and enthusiastic. At one point around 1983 we organized a football team and played once a week (see Figure 1b). The team lasted for several years, but I stopped one day in 1985 after a painful fall.

Figure 1a. Meeting of the photoelectrochemistry group in the seminar room of the Levine building ca. 1981. Standing from left: Baruch Vaines, Dr. Reshef Tenne, Prof. Joost Manassen, Dr. Gary Hodes, Dr. David Cahen, Menashe Lev, Harvey Flaisher and Stuart Licht; Sitting: Tina Engelhard .and Geula Dagan

Figure 1b. Soccer team of the Department of Plastics Research. Standing from left: Eyal Sabatani, Israel Rubinstein, Shlomo Margel, Yves Tricot, Dan Frenkel; kneeling from left: Zelu Itzikovitz, Daniel Wagner, Reshef .Tenne, Baruch Ittah

Reshef Tenne earned his PhD in 1976 in the Hebrew University. He joined the Weizmann Institute in 1979, where he was promoted to professor in 1995. In 1992, he discovered a new family of nanomaterials - the so-called inorganic nanotubes (INT) and fullerene-like (IF) nanoparticles from layered compounds (2D materials). He and his research group synthesized and studied many kinds of IF/INT. In the last decade, he studies mainly nanotubes from "misfit" layered compounds consisting of 3-5 elements each. His work led to the development of a new technology for solid lubrication and serve also as additives to reinforce polymer composites with myriad of applications. He received numerous awards, including MRS Medal (2005), the Israel Chemical Society Excellence in Research Prize (2008), Rothschild Prize (2016) and recently the Technology Award of the International Union of the Vacuum Societies (2019) and the EMET Prize (2020). He is a member of the Israeli Academy of Sciences and Humanities and is currently Research (Emeritus) Professor at the Weizmann Institute.



Prior to my appointment at the Weizmann Institute, I had little experience with electron microscopy. Electron microscopy, however, was not new at the Weizmann Institute. In fact, Prof. David Danon z"l and Dr. Yehuda Marikovsky z"l had already established the first transmission electron microscopy lab for life science research in 1955. Figure 2 shows the tranmission electron microscope being moved on a horse wagon in 1963 to the then new Ullman building. Also, some work with scanning electron microcopy of semiconductor surfaces had been done by Dr. Gary Hodes and Dr. David Cahen in the late 1970s, based on instruments available at the Hebrew University of Jerusalem, both on the Givat Ram campus and the Faculty of Agriculture campus across the road from the WIS.

Figure 2. The transmission electron microscope is moved to a new lab in the Ullman building in 1963. See Weizmann Wonder and Wander report– https://wis-wander.weizmann.ac.il/life-sciences/someone-operate-it-and-place-put-it

As soon as I joined the Institute, I started working on the modification of semiconductor surfaces and in particular CdSe, for application in photoelectrochemical solar cells. Observing that upon light-induced acid-etching the semiconductor surface becomes very opaque and highly responsive to light, I took it for a scanning electron microscopy (SEM) analysis. Since there was no electron microscopy (EM) facility for studying materials at the WIS, I made extensive use of the SEM facility of the Faculty of Agriculture of the Hebrew University across the road, which was operated by Mrs. Naomy Bahat (under the supervision of Prof. Avraham Shahar z"l). Unfortunately, this SEM did not have an energy dispersive X-ray spectroscopy (EDS) detector and I was obliged to go elsewhere to perform chemical analysis of the CdSe-etched surfaces. I decided to try to convince the management of the institute to buy an SEM/EDS set-up. I talked frequently with my department head – Prof. Moshe Levy z"l and Prof. Joost Manassen z"l on this issue, but since I was a young investigator without tenure, my influence on the decision-making process was not high. After a few refusals, the President of the Institute – Prof. Michael Sela graciously agreed to contribute money for this undertaking. Then one day in 1983 I was invited to the cramped (mini)office of Prof. Mordechai Avron z"l, the VP for Scientific Affairs (Rector) in the Ullman building. He gave me permission to buy an instrument and to hire a person to run this system, with the strict condition that it would be placed in the existing electron microscopy (EM) unit dedicated to research in life sciences. Subsequently, I went to the head of this unit, Dr. Victor Ben-Giat, and while approaching his small office in the basement of the old Wolfson building, I noticed a mouse watching me attentively – a most auspicious welcome to the EM unit, which was next to a mice-breeding unit. At that time the EM unit possessed only a few Philips TEMs. The most modern one there, the EM400 TEM, see Figure 3, was equipped with a scanning transmission electron microscopy (STEM) console, which had rarely been used. It belonged to the Biological Services Department, supervised by Dr. Yoram Solomon z"l, who was very receptive to the idea of adding an SEM for materials research to this unit.

Figure 3. Dr. Victor Ben-Giat and Mr. Carol Bakalsh with the EM 400 TEM in the old Wolfson EM lab

Victor located a small dark room for the SEM in the EM unit. Since I was not an expert in the field, I was advised by Lia Addadi (now a professor in our faculty) to go to the TAMI Institute in the Haifa Bay, where Dr. Eugenia Klein operated one of the first SEMs with EDS in the country and learn from her experience. Once there, I met Eugenia who had graduated from the Department of Structural Chemistry in the WIS under the supervision of Prof. Mendel Cohen z"l. I was so impressed with her deep knowledge of SEM/EDS, that I told Victor that we must hire her for the job. Soon after, Eugenia and I found ourselves examining a few SEMs in various corners of the country. I recall a joint trip to the Degania B factory for cutting tools to study their set-up. We also visited the Jordan Valley company in Migdal Ha-Emek to see their line of SiLi drifted detectors for EDS. In the summer of 1983, I went to work in the CNRS in Meudon near Paris. Prior to that, I spent a few days with my family in Eindhoven, home of Philips, and it became apparent to me that the Philips SEM 505 (which was later upgraded to the 515 model) with EDS analyzer of Tracor-Noran would be the most suitable system for us – see Figure 4. The EDS analyzer came with large (12 inch) red-color storage media and a computer of 32 or 64 k. This SEM/EDS served us for 15 years, if not longer, with a few upgrades of the software and the interface electronics.

Figure 4. The Philips 505 SEM in the De-Leonesco EM lab

I started my journey into 2D materials (layered compounds) in 1984, after receiving a large bright crystal of WSe_2 from Prof. A. Wold z"l of Brown University, who visited the WIS at the invitation of Dr. David Cahen (now a professor at our faculty). In a short time I learned how to passivate the material surface, obtaining exceedingly good photoresponse and reporting record solar-to-electrical conversion efficiencies (> 13%) for solar cells based on 2D materials. Using the Philips 505 and EDAX analyzer, I could clearly see the beautiful pattern of hexagonal etch pits on the WSe_2 surface, which emerged from screw dislocations on the semiconductor surface (see Figure 5).

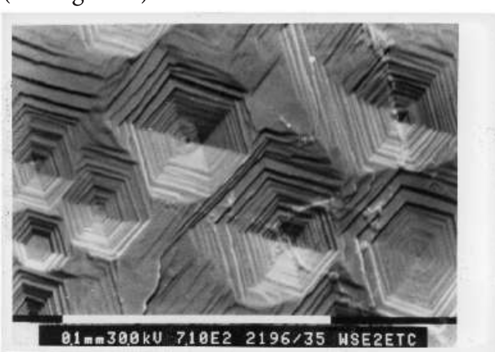


Figure 5. Etch pit pattern on the surface of surface-passivated WSe_2 crystal

In November 1987, at the initiative of the then President of the Institute – Prof. Aryeh Dvoretzky z"l, the EM unit was moved to a dedicated new facility in the de-Leonesco building. Around that time, the EM unit was transferred to the administrative responsibility of the Chemical Research Support Department, previously called Chemical Services, which was a blessing for the EM unit. I vividly recall the inauguration ceremony with Mrs. De-Leonesco z"l seated behind Prof. Dvoretzky (see Figure 6). We were obviously delighted to have been moved from the "slums" in the basement of the old Wolfson building, with frequent visits from mice and the odor of their excrement, to a modern air-conditioned building.

Figure 6. Inaguration ceremony of the De-Leonesco EM lab, 9.11.87. Speaking Prof. Aryeh Dvoretzky; sitting from the left: Prof. Yoram Groner, Adv. Moshe Porat, Mrs. De-Leonesco, Sir Marcus Sieff, Mr. Robert Parienty

In 1989 Prof. David Cahen and I were contacted by a newcomer from the Moscow Institute of Steel and Alloys – Dr. Lev Margulis z"l, who was an expert in TEM and electron diffraction (ED) of silicon wafers. At the first interview he told us his story. He had learned basic Hebrew in a clandestine site in Moscow and consequently was a Refusnik for several years and lost his job as a researcher. He suffered what appeared to us terrible anti-Semitic discrimination and hardships, but he never gave up his Zionistic dreams, and his perserverence eventually won out. We described to him our science where silicon had no role whatsoever. It took probably two more meetings to see that we had no common interests, and the three of us were heartbroken. On the one hand, both David and I did not have any interest in the TEM analysis of silicon dislocations, but we felt that here we had an expert in the TEM of materials, whom we could not afford to turn down. We developed a great empathy to Lev, which paid off handsomely in the years to come. We decided to hire him for a trial period of a few years. Our decision was greatly facilitated by granting him initially the Shapira Fellowship for immigrants, and subsequently the Gilaedi Fellowship from the Ministry of Absorption (Misrad Haklita). Already in 1987, one student of David, David Soltz, following a visit to Germany, built an early version of an electron beam induced current (EBIC) set-up, the first of its kind in the country, which permitted characterization of semiconductor junctions *in-situ* in the SEM. Later on using this set-up, David's post-doc Dr. Abraham Jakubovicz, who afterwards went to IBM Zurich, my student Diana Mahalu, and Lev Margulis jointly studied the charge transfer across WSe_2-gold interfaces and published a few remarkable works in *Phys. Rev. B* on this topic.

Sometime around that period, another immigrant from the former Soviet Union, Dr. Konstantin Gartsman started his career in David's group further upgrading the EBIC set-up. Together with a slew of excellent students – Leonid Chernyak (now a professor at Florida State University), Igor Lubomirsky (now a professor in our department at the WIS), they were able to obtain, using the EBIC/SEM, a series of groundbreaking results on ion migration in semiconducting lattices under the influence of electric field and light.

When I came back from my sabbatical in the laboratory of Prof. C. Levi-Clement in the CNRS Meudon (near Paris) in 1989, it became apparent to me that I wanted to stop etching semiconductor surfaces and instead start growing new materials. Having already worked with 2D materials for five years, I decided to try to study photoelectrochemical cells made of thin film MoS_2 and WS_2, which were prepared by chemical bath and electrochemical deposition techniques (jointly with Prof. Gary Hodes). While spending a few months in the laboratory of Prof. A. Fujishima in the University of Tokyo in the summer of 1991, I read the news of the discovery of carbon nanotubes by Dr. S. Iijima. I started questioning myself (and later on Prof. Gary Hodes) if it would be possible to prepare fullerenes and nanotubes from other 2D materials, such as WS_2 and MoS_2. Independently, during that summer (1991), Dr. Lev Margulis was using the EM400 TEM to study the structure of the WS_2 and MoS_2 films prepared by my post-doc Dr. Menachem Genut. He found strange nanostructures, which he designated as "red blood cells", because they appeared like donuts, i.e. circular nanoparticles with low contrast in the middle. Figure 7 left shows a picture of one of the original envelopes for the storage of TEM negatives with Lev's handwriting. Without going into too much detail, after a few months of pondering these results, I concluded that these nanoparticles, designated as inorganic fullerene-like (IF) and inorganic nanotubes (INT), are the multiwall analogues of carbon fullerenes and carbon nanotubes – see Figure 7 right for a typical TEM image of one such nanotube. After publishing a few joint papers in *Nature* and *Science* on these nanoparticles, Dr. Lev Margulis passed away unexpectedly in the summer of 1995. Earlier, Talmon Arad z"l, a TEM expert, who collaborated with Prof. Ada Yonath (Nobel Laureate) while at EMBL, Heidelberg, joined the Weizmann Institute. At his request, the Institute bought a new cryo-TEM the CM12, which had low contrast and no electron diffraction capability, but better resolution than the EM400. Talmon started working with Lev, too, and they got along very well until the tragic death of Lev (see Figure 8).

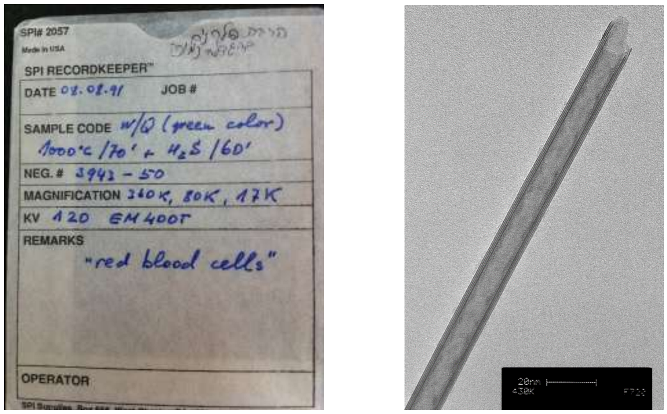


Figure 7. Left: Copy of an original envelope for storing TEM negatives with the hand-writing of Dr. Lev Margulis (the more recent comment written with pencile in Hebrew on the top is mine); Right: TEM image of a WS_2 nanotube

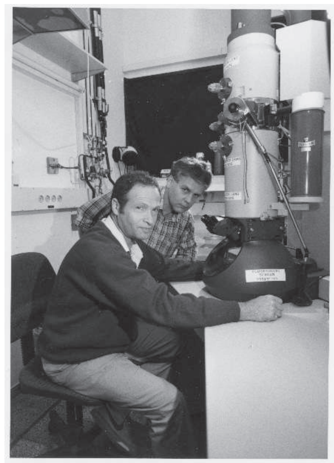


Figure 8. Dr. Lev Margulis (seated) and I (leaning) near the CN12 TEM (from 23.11.92).

Prof. Enrique Gruenbaum z"l, who had retired from Tel-Aviv University and made remarkable contributions to Lorentz microscopy of magnetic materials, joined us around 1995 as a consultant in my group. He helped Yaron Rosenfeld-Hacohen analyze his newly discovered $NiCl_2$ nanotubes and fullerene-like nanoparticles. Enrique was travelling via boats and trains to Oxford University almost every summer (he did not dare to fly). There he worked with Dr. John Hutchison, the foremost TEM of materials expert of that university at the time. John was using the high resolution JEOL 400 keV machine. He had several talented students with him – Jeremey Sloan (now a professor at Warwick University) and Rafal Dunin Borkowski (currently a professor at RWTH Aachen University and the director of the Ernst Ruske Center in Jülich – one of the foremost electron microscopy facilities in the world). With their help, we gained the first high resolution TEM images of WS_2 and MoS_2 nanotubes.

Following the tragic loss of Dr. Lev Margulis our research on IF and INT suffered from a lack of TEM expertise. Nonetheless, my research got a boost from a fortunate turn of events. Graciously, Prof. Meir Lahav, the department chair offered in 1997 to transfer Dr. Ronit Popovitz-Biro, a researcher in his group, to replace Lev. To our surprise, in a year or two, Ronit became fully versed with electron microscopy and started producing splendid results with the CM12 and later with the CM120. At one point in 1998 we submitted our first paper on $NiCl_2$ nanotubes to *Nature*. After some time the report came back from the journal. One of the referees argued, justifiably, that the data lacks an EDS (chemical) analysis of the nanotubes. Indeed none of the existing TEMs in the EM unit was earmarked for materials research and consequently we had no access to EDS/TEM set-up. I was extremely disappointed, because I believed that our $NiCl_2$ tubes and fullerenes were not sufficiently stable against humidity and they were scarce. At the advice of Prof. Meir Lahav, I went directly to the Vice-President Prof. Yoram Groner to complain. Under his supervision, it took no longer that two months to install the wonderful CM120 which was a boon to our research. The CM120 operated smoothly until five years ago when it was retired due to the arrival of the new JEOL2100. In the meantime, Dr. Ana Albu Yaron (Angie) who had just retired from her post in the Volcani Center and worked frequently with Dr. John Hutchison in Oxford, joined our group as a consultant. Angie was an extremely dedicated microscopist and I admired her tenacity and patience. Perhaps the culminating point of her work was the synthesis and analysis of IF-Cs_2O nanoparticles in 2005. These unique nanoparticles were inflammable in the ambient and therefore we built and installed a dedicated drybox and attached it to the CM120 – see Figure 9 (left). This add-on allowed us to transfer the inflammable nanoparticles without any exposure to the ambient atmosphere. One reason that these rare nanoparticles were incredibly difficult to find and analyze was the somewhat bizarre fact that the TEM column was contaminated with IF-WS_2 nanoparticles synthesized by my other students and the Cs_2O nanoparticles could not be easily discriminated and analyzed.

Prof. Lia Addadi and Prof. Steve Weiner did pioneering work on biomineralization at the WIS. Around 2000, FEI (successor to Philips) came up with an ingenious SEM, which can analyze samples under a moderate pressure of few mbars of water vapor. This development made it possible to image both biological samples under close to live conditions and highly insulating polymer specimens, saving the otherwise tedious coating process with a thin gold film. Using several hardware and software modifications, this microscope (Figure 9, right) was converted by Ifat Kaplan-Ashiri into a full nanomechanical testing set-up, during the preparation of her PhD thesis.

Around 2000, while Prof. David Cahen served as the academic head of the EM unit, discussions started about adding an NMR unit for brain research next to the EM unit. Following consultations with the EM manufacturer – Philips, it became clear that instalment of a nearby NMR unit would jeopardize the resolution of the electron microscopes due to interference with the strong magnetic fields. One day, the President of the Institute – Prof. Haim Harari contacted me and said that he was ready to offer the EM unit the two lower floors of the old Wolfson building, which was undergoing renovation. He asked me to go and visit the site and then call him back. I went there and other than smelling the nasty odor of the mice, I noticed that the ceiling was too low to accommodate a modern high-resolution TEM. I called back Haim and told him that the level of science there will not be higher than the height of the ceiling itself. He immediately recognized the problem and said he would build a room with an extra-high ceiling for the future high-resolution TEM (HRTEM). The next day he called me again and said that he had changed his mind and decided to build a whole new annex to the old Wolfson building with a room for six advanced microscopes.

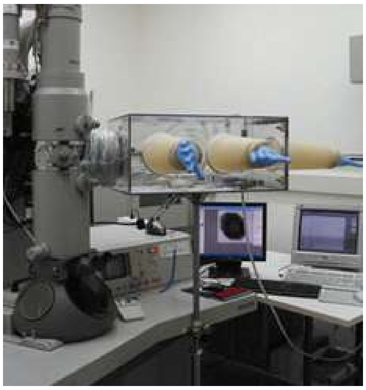


Figure 9. Left: The CM120 TEM with the "perspex" glovebox attached to the sample introduction chamber; right: Dr. Eugenia Kelin and Ifat Kaplan-Ashiri working with the E-SEM.

Obviously, I was enthusiastic and impressed by his far-sighted vision. Figure 10 shows an overall picture of the EM facility at that time. We of course know now that even the higher ceiling there is not adequate for the new generation of aberration (*Cs*)-corrected TEM, but at the time it was the greatest present he could possibly offer us. The new EM center was very well planned to allow cryo-microscopy with 20% humidity for biological specimens and also equipped with a very modern and quiet air-conditioning system. To verify that the acoustic noise would not exceed the specifications of the company for HRTEM, Prof. Mudi Sheves – the then Dean of the Faculty, hired a municipal garbage truck, which travelled back and forth along the road separating the EM center from the power center of the WIS, with no noticeable effect on the noise level, which could jeopardize the future TEM performance.

Figure 10. View of the current EM lab in the old Wolfson building and the annex hosting some of the high-performance SEMs/TEMs in the foreground. The Wolfson building is in the background.

Dr. Sharon Wolf, currently the director of the EM unit, joined the unit in 1998 and slowly geared her efforts towards electron tomography. Around 2004 it became clear that a new generation of microscopes was needed for both life sciences and materials research. In particular, the lack of high-resolution TEM (HRTEM) became a stumbling block for us and we desperately pleaded with the management to buy one for us. Luckily, the life scientists and, in particular, Dr. Sharon Wolf also needed a new cryo-HRTEM for their electron topography experiments. Under the leadership of our Dean, Prof. Mudi Sheves, we slowly crystallized our ideas and established a deal with FEI (the successor of Philips) to buy the Cryo F20 (200 keV) for the life sciences and the F30 HRTEM (300 keV) for materials research. Figure 11 shows Ronit working with the F30. Unfortunately, we lacked the expertise and did not buy the STEM unit and consequently HAADF experiments could not be done on this microscope. However, the quality of the HRTEM run by Dr. Ronit Popovitz-Biro was so high that at one point Dr. Lothar Houben, who later joined the EM unit to head the Titan Themis project, remarked that with Ronit and F30 we have 95% of the capacity of a *Cs*-corrected Titan, which although not completely accurate, was a great compliment to her.

Figure 11. Dr. Ronit Popovitz-Biro at work with the high-resolution F30 TEM. Note the acoustic noise shielding on the walls and the cylindrical power-supply tank delivering 300 keV

Some 18 years ago two excellent students joined my group, Ifat Kaplan-Ashiri and Maya Bar-Sadan. While Ifat made the first in-situ SEM measurements of the mechanical properties of WS_2 nanotubes, Maya became interested in the synthesis of MoS_2 nanooctahedra, which are considered to be the smallest hollow cage structures (IF) of that compound. Following a post-doctoral spell in Austin Texas, Ifat joined the EM lab becoming the head of the SEM section. At my encouragement, Maya started to look for a place where she could carry out detailed TEM analysis of the MoS_2 nanooctahedra. Finally, she ended up in the laboratory of Prof. Knut Urban, who headed the Ernst Ruske Center in Juelich, one of the largest TEM facilities in the world if not the largest one. Under his supervision, the first aberration (*Cs*) -corrected TEM was developed in 1998 demonstrating the first sub-Angström resolution. In fact, our first work using this revolutionary TEM technique (*PNAS*, 2008) was published as a result of this collaboration. Over the years, I collaborated with various laboratories, mostly in Europe, to gain access and analyze our nanotubes with the latest technology in *Cs*-corrected TEM. Sometime around 2013, I started to nag my department chair Prof. Leeor Kronik and the then Dean (Prof. Gilad Haran) that *Cs*-corrected TEM is a must on our campus. At their encouragement I sent a detailed letter to the then President (Prof. Daniel Zajfman). Coincidentally, Prof. Ada Yonath understood that the future of protein structural elucidation is in cryo-TEM. Unexpectedly, and to my delight, Maya became a life-partner with Dr. Lothar Houben who is one of the leading experts in *Cs*-corrected TEM/STEM. Upon returning to Israel in 2011 and joining the faculty of Ben-Gurion University, she convinced Lothar to join her in Rehovot in 2015 and he received an invitation to join the EM center and establish the *Cs*-corrected TEM unit at the WIS. It takes vision and courage to make a major decision, like the one taken by our former President Prof. Daniel Zajfman to upgrade the EM unit to its present status. In fact after 40 years that I have been preaching for electron microscopy in our campus, this is the first time that the WIS runs an electron microscopy facility which is state of the art. Figure 12 shows a global view of the new high-resolution TEM facility of the WIS, which operates in highly modern and well planned premises in the new Benoziyo building. This was of course not achieved through purchase of upgraded SEMs and TEMs, alone. Hiring experts to run the EM center is no less important and I wish to congratulate the new EM facility and especially the staff and hope they will go from strength to strength. (https://www.weizmann.ac.il/ChemicalResearchSupport/electron-microscopy/instrumentation)

Figure 12. The new high-resolution TEM facility in the basement of the new Benoziyo building hosting the Titan Themis (left), Titan Kryos (middle) and the Talos Arctica (right) TEMs

I would like to conclude my personal account on the history of the EM-materials efforts by saying how grateful I am to the Weizmann Institute, which spared no effort or resources to make the entire EM unit a remarkable success story and thank all the current and past researchers and staff of the EM unit for their dedication. I wish to emphasize that this piece reflects my personal perspective of the historical development of the EM center, which is naturally focused on hard materials. I skipped important aspects of the EM center, which are dedicated to soft matter and biology or a combination of soft and hard matter and was pursued by other researchers at the WIS campus. I apologize if I missed any important aspect and people in my personal account of the contemporary history of the EM facility.

Advanced Materials in Israel Chemical Industry and Mexico Medical Research: Science, Technology and Innovation

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Abstract: We report on international cooperation between Mexico and Israel that started in 1992 and has been active over the last three decades. Scientists and engineers from the Technion – Israel Institute of Technology and the Sami Shamoon College of Engineering - both in Israel - worked together with scientists and engineers from the Universities of Baja California, Campeche, Veracruz, and Merida, in Mexico. Also involved were Israeli industrial companies, which – based on the nation's natural resources – developed new processes for making valuable products. These included: industrial acids (e.g., sulfuric acid, phosphoric acid, nitric acid, and hydrochloric acid), minerals (e.g. periclase, magnesium oxide), fertilizers (e.g. potassium chloride, potassium nitrate), halogens (e.g. chlorine, bromine), and metals (e.g. copper, magnesium). Also used were novel engineering materials, such as alloys (e.g. nickel (Ni)-alloys, austenitic stainless steels, aluminum (Al)-alloys), plastic materials (e.g. rigid poly (vinyl chloride), poly (propylene), Teflon), and composite materials (e.g. fiberglass – reinforced polyester, glass, steel-coated glass). Some of the latter products were adapted for the manufacture of industrial equipment for use in Israeli chemical plants. In Mexico, investigations focused on medically oriented materials and, particularly, on metallic orthopedic implants. Thus, coating of the titanium alloy (Ti6Al4V) with titanium dioxide (TiO_2) nanotubes endowed it with antibacterial and antifungal properties, while coating it with hydroxyapatite improved its biocompatibility with osseous tissues.

Introduction

The National Council of Science and Technology (CONACYT) is officially designated as a decentralized public agency of Mexico's federal government. In that role, it promotes the establishment of cooperative relations with recognized academic institutions such as universities and research institutes. The central aim of CONACYT is to conduct research, education and training programs that address issues related to science and technology of advanced materials, medical research, and industrial corrosion, to help solve the social and economic problems of society and the nation.

Research cooperation is a valuable tool to promote the scientific and technological progress necessary for the progress of a country. The results obtained are beneficial to educators for the adaptation of novel teaching methods and for students seeking to learn new approaches toward problem solving.

Leading this collaboration is the Institute of Engineering, Autonomous University of Baja California (UABC), together with Mexican participants, the Universities of Campeche, Veracruz, and Merida. The Israeli participants are the Technion- Israel Institute of Technology in Haifa, and the Sami Shamoon College of Engineering, with campuses in Beer Sheva and Ashdod.

These institutions work together in activities such as faculty exchange; collaborative research and joint publications; reciprocal visits to present lectures, seminars, and courses; participation in national and international congresses, and exchange of academic materials and information.

This paper provides a chronological overview of the collaboration and describes the various activities emanating from it.

The Mexico-Israel cooperation – chronological overview

CONACYT, under the auspices of the Secretary of Education in Mexico established a Corrosion Research Institute - "Programa de Corrosion del Golfo de Mexico" (PCGM), under the framework of the University of Campeche [1]. The PCGM is located in one of the most strategic areas in Mexico, and is the site of the natural petroleum industry managed by PEMEX, Petroleos Mexicanos. The institute deals with corrosion prevention and infrastructure control, fishing ships, coastal buildings, ports, river bridges, water supply systems, power generation stations, and oil marine platforms. Its primary concern is the permanent modernization of the infrastructure.

J. Yahalom of the Corrosion Department, Faculty of Materials, Technion-Israel Institute of Technology, visited the PCGM and presented lectures and courses on control of marine corrosion. G. Duque, director of the PCGM, visited both the Technion, and Haifa's Israel Mining Industries (IMI) Institute for Research and Development (now known as IMI-TAMI Institute for Research and Development Ltd.) to learn and establish a cooperative relationship with them.

In 1994, the Technion President invited Mexican ambassador, Rafael Rodriguez Barrera, to visit the Technion, to acquaint him with Israel's scientific, technological, and industrial developments. Yahalom organized the visit, which focused on advances in engineering materials, supply and distribution of energy and water (including seawater desalination), and the chemical and fertilizer industries. It is noteworthy that Barrera was the past governor of the Mexican state of Campeche, and supported the creation, construction, and operation of the PCGM. During this visit to Israel, Barrera was accompanied by G. Hernandez, B. Valdez, and M. Schorr, who were involved in the design, construction, and operation of the PCGM Corrosion Laboratory, with its modern equipment.

During this one-week visit, Yahalom, Duque, and Schorr were introduced to the industrial establishment in the Haifa area, with visits to IMI's national research and development institute; Oil Refineries, Ltd. (ORL); Tambour paints factory; Naaman ceramics industry, and the Haifa naval shipyard.

Following that visit to Israel, the collaboration was pursued at multiple levels ranging from advanced studies at the Technion for Mexican postgraduate students and reciprocal visits to Mexico and Israel, to industry visits in pursuit of additional industrial collaborators, as detailed below.

A PhD student from Mayab University, Merida, Yucatan, studied under Yahalom at the Technion. Members of PCGM visited and assisted personnel of the phosphoric acid (PA) plants, in Coatzacoalcos, Veracruz State, where wet and solvent extraction (SX) processes, and corrosion control methods were used.

In 2003, the UABC created an interdisciplinary "Center for Desert Studies" within the framework of the Institute of Engineering. The center dealt with water, energy, climate, agriculture, environment, health, rock art, and desert survival. A. Eliezer (Corrosion Research Centre (CRC), Sami Shamoon College of Engineering, Beer Sheva and Ashdod) and Schorr also visited the Jacob Blaustein Institute for Desert Research, Ben-Gurion University of the Negev, Sde Boker, to establish a tripartite cooperation; however, the center's budget was closed and its activities were interrupted, although some information emanating from this cooperation was published [2].

N. Lotan, Department of Biomedical Engineering, Technion-Israel Institute of Engineering, visited Mexicali in 2005 and 2007. Lotan gave lectures and seminars to institute members and its graduate students on the topics of biocorrosion of metallic and polymeric implants in the human body, and intelligent materials such as hybrid assemblies. He also gave a full-day seminar for students and the general public on scientific and technological aspects of orthopedic implants in the human body, at the University of the Mexican State of Aguascalientes, with the participation of Hernandez. Lotan continues to provide guidance for improving and preparing our publications [3-5].

Eliezer's work focused on corrosion of light metals: Al, magnesium (Mg), and Ti use in the naval and automotive industries; performance of Ti hip orthopedic implants coated with hydroxyapatite; behavior of infrastructures in the desertic land of the Negev in Israel and Baja California, Mexico; marine corrosion in the ports of Ashdod, the Mediterranean Sea, and Ensenada in the Pacific Ocean.

In 2006, Lotan and Eliezer presented lectures at an international symposium on Advanced Materials Science and

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Engineering, on the topic of fundamentals, characterization and application, in Mexicali.

The CRC organized two international conferences in Beer Sheva in 2007 and 2011, on "Corrosion, Advances Materials and Processes in Industry," with the participation of Israeli, Mexican, American, and European materials scientists and corrosion practitioners.

From 2007–2017, Schorr made short visits to Israel to participate in teaching, research, and guiding CRC students as they prepared for their BSc, theses and graduation exams in Beer Sheva. Two students from the UABC Institute of Engineering spent periods of study and teaching preparing their postgraduate thesis under the guidance of Eliezer.

The Metals, Minerals, and Materials Society (TMS), an international organization located in the United States (US), and the Technion's Institute of Metals organized a joint congress on "Technological Innovation and Metals Engineering" (TIME). Eliezer presented the invited lecture.

The Institute of Engineering, UABC, Baja California, invited two corrosion experts: R. Serousi, the director of the Paints Research Laboratory, Tambour Paints Company, and A. Groysman past director of the Corrosion Laboratory at ORL, to give lectures on their areas of specialization; however, due to travel difficulties they could not accept. Groysman subsequently published an interesting book about the scientific, economic, technical, social, historic, and literary aspects of corrosion, from which the academic personnel and students of the Institute of Engineering derived benefit [6].

The role of the Israel chemical industry

The creation of chemical industry involves two units: the processing unit that initiates chemical reactions, and the operations unit, where physical methods of separation are applied. The combination of these processes converts new materials into valuable consumer products.

The chemical process industry (CPI) deals with aggressive chemicals: i.e., the most corrosive of the acids, bases, salts, halogens, oxidants, and solvents. Therefore, chemical plants designers, constructors and operators seek corrosion-resistant materials (CRM) for the fabrication of useful chemical processing equipment (CPE). The most modern CPE involves metallic, plastic, ceramic, composites for the manufacture of pumps, valves, pipes, agitators, reactors, heat exchangers, filters, centrifuges, scrubbers, distillation trays, and tower packings – many made of corrosion-resistant alloys (CRA).

Corrosion prevention, mitigation, and control in the CPI are based on three general methods:
- Correct selection of CRM for the manufacture of the plant equipment, installations, and structures that are compatible with the fluids used by each plant.
- Protection of CPE using industrial paints, polymeric coatings, and rubber linings that are resistant to the plant fluids.
- Application of cathodic protection, by impressed current or sacrificial Al and Mg anodes, to prevent structural corrosion.

The economic importance of the phosphoric acid industry (PAI) is evidenced by the establishment of the International Symposium on Innovation and Technology in the Phosphate Industry (SYMPHOS), and by the publication of several books [7, 8] that provide a basic knowledge of PA characteristics.

Phosphoric acid processes: classical and novel

The IMI Institute for Research and Development was founded by Abraham Baniel in 1959. He served as its director from 1959-1973, and established collaborations with national and international institutions on the development of CPI based on Israel's natural resources [9]. The IMI's main activity centered on the creation of processes for the production of both classical and novel phosphoric acid (PA) [5]. The characteristics of the phosphate rock (PR), the PA, and its derivatives for various applications are described in several publications [10].

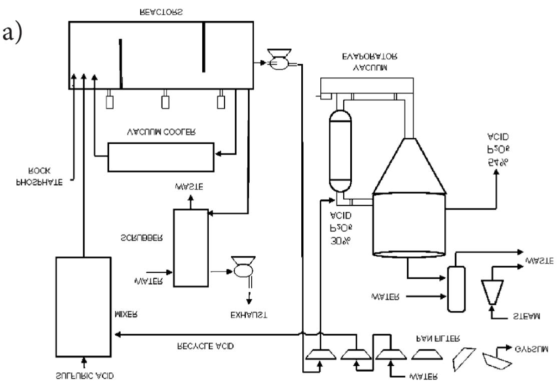
Benjamin Valdez was the director of the Institute of Engineering from 2006- 2013, Universidad Autonoma de Baja California, Mexicali, Baja California, México. He has a BSc in chemical engineering, an MSc and PhD in chemistry, and is a member of the Mexican Academy of Science and the National System of Researchers in Mexico. He was the guest editor of Corrosion Reviews, in which he produced two special issues on corrosion control in geothermal plants and the electronic industry. He is a full professor at the University of Baja California. His activities include corrosion research, consultancy, and control in industrial plants and environments. During the IMRS Congress, in August 2013, in Mexico, he received a "Distinguished Service Award" from NACE International and the NACE Central Mexico Section. He has been a NACE International member for 26 years. benval@uabc.edu.mx

A critical problem in PA production is the appearance of various types of localized corrosion, e.g. erosion-corrosion. The IMI organized a corrosion group, with a corrosion laboratory to test materials candidates for the PA plants and to serve Israel Chemicals Limited (ICL) plants for solutions of corrosion problems [11-13].

Both PA processes (wet and SX; Figures 1a and 1b, respectively) were improved by selecting new, innovative materials for fabricating plant production equipment. For the wet process, austenitic stainless steels, produced by American and European CRA companies, were used to manufacture reactor agitators, centrifugal pumps, and filtration pans. For the SX process, rigid polyvinyl chloride (PVC) produced by Palram (located in Ramat Yonathan, Israel, and with a plant in Monterrey, Mexico) and fiber-reinforced polyester or epoxy, produced by the plant technicians, were used for reactors, agitators, mixer settlers, solvent recovery columns, and hydrochloric acid (HCl) concentrators, since they are resistant to solvents and to mixtures of solvents-acid

The IMI PA technology, which includes the process fundamentals, the plant design, the equipment materials, and the central corrosion techniques, has been sold to the Brazilian petroleum industry, the Shah of Persia, Government of India, Fertimex – a company in the Mexican fertilizer industry, and Spanish fertilizer enterprises.

a)



b)

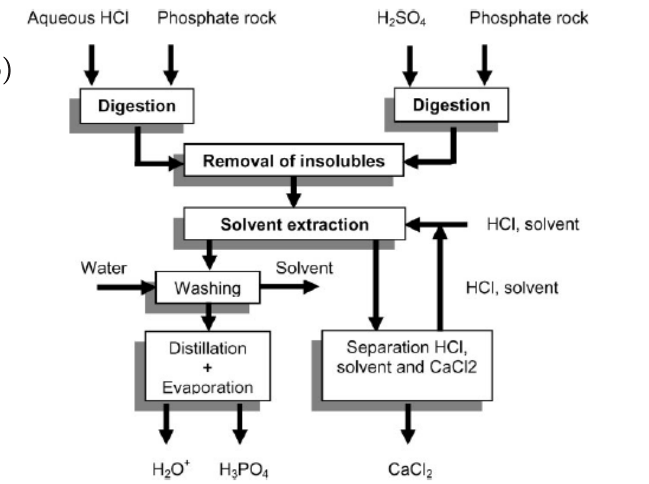


Figure 1. The wet (a) and solvent extraction (b) process for phosphoric acid production.

Timna copper production

In ancient times, Egyptian metallurgists produced copper (Cu) by reducing mineral Cu by burning carbon in the holes of rocky soil:

$$CuSO_4 + C \rightarrow Cu + CO_2 + SO_2\,. \qquad (1)$$

IMI developed a chemical process for the production of Cu at Timna Valley mines, which involved digesting malachite with sulfuric acid (H_2SO_4):

$$Cu_2CO_3(OH)_2 + 2H_2SO_4 \rightarrow 2CuSO_4 + CO_2 + 3H_2O. \qquad (2)$$

Cu was then precipitated by addition of iron junk:

$$CuSO_4 + Fe \rightarrow Cu + FeSO_4. \qquad (3)$$

Grupo México, owner of Cu mines in Mexico acquired the Timna plant with the intention to operate it, but the project was closed due to the low price of Cu on the international

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metal market. (Video: Grupo Mexico, Copper Mines: https://www.youtube.com/watch?v=0B7fFEoMBZ8)

The byproducts, solutions of copper(II) sulfate ($CuSO_4$) and manganese(II) sulfate ($MnSO_4$), were evaporated in ponds, taking advantage of the elevated temperature and dry winds of the Arava desert.

Dead Sea Works: chemicals

The Dead Sea Works (DSW) water system is composed of brackish waters, ponds for evaporation, and pipelines made of steel, concrete, and PVC [14]. The Dead Sea is a closed sea, containing salts, potassium chloride (KCl), sodium chloride (NaCl) and magnesium chloride ($MgCl_2$); it is saturated at 25% concentration. These salts constitute an excellent source for production of chemicals, fertilizers, and Mg.

A concentrated sylvinite brine (KCl-NaCl) is heated in a Ti plate heat exchanger (PH) and separated into two products NaCl and KCl (potash). NaCl is then converted into chemicals by electrolysis:

$$2NaCl + 2H_2O \rightarrow Cl_2 + H_2 + 2NaOH. \tag{4}$$

The anodes are made from Ti alloy covered with titanium dioxide (TiO_2) for protection. Additional equipment in the chlor-alkali plant is fabricated from Ti alloys: chlorinators, steam machines, stripping columns, piping, valves, pumps, agitators, and fasteners.

Bromine (Br_2) is produced by oxidation:

$$2NaBr + Cl_2 \rightarrow Br_2 + 2NaCl. \tag{5}$$

In the past, the chlorinators and stripping were made of glass. A new process utilizes a titanium/palladium grade 11 (Ti-1.5Pd) alloy.

A concentrated $MgCl_2$ brine is sent from the DSW by steel pipeline to the Periclase plant in the Rotem Valley, where it is converted at high temperatures in a Herreshof calciner:

$$MgCl_2 + H_2O \rightarrow MgO + 2HCl\,. \tag{6}$$

The hydrochloric acid (HCl) is applied in the production of PA at the Haifa Chemicals Plant (see next section).

Haifa Chemicals: fertilizers

IMI continued exploring the mineral resources of Israel, converting KCl into a high value fertilizer: potassium nitrate (KNO_3). Baniel proposed to oxidize ammonia (NH_3) into nitric acid (HNO_3), and then react it with KCl, to produce a special fertilizer. The byproduct, HCl, would then convert PR into H_3PO_4, according to the following chemical reactions:

$$NH_3\,(g) + 2O_2 \rightarrow HNO_3\,(aq) + H_2O, \tag{7}$$

$$KCl + HNO_3 \rightarrow KNO_3 + HCl, \tag{8}$$

$$Ca_3\,(PO_4)_2 + 6HCl \rightarrow 2H_3PO_4 + 3CaCl_2. \tag{9}$$

For this project, Haifa Chemicals received the support of ORL. The SX technology was applied using an industrial alcohol as solvent, thereby obtaining corrosive aqueous and alcoholic solutions. It should also be noted that Haifa Chemicals operates a network of Mexican companies for the distribution of its fertilizers.

New, advanced engineering materials were needed for this original process and to produce the proper chemical equipment for plants. Ti alloys were selected for the manufacture of tube or plate heat exchangers (HX), centrifuge pumps, valves, and thermowells. Fluids storage vessels and mixers-settlers were made from rigid PVC sheets (ex-Palram) and/or fiber-reinforced polyester FRP.

Ernesto Beltrán-Partida obtained his BSc in biological and pharmaceutical chemistry and his PhD in biomaterials sciences, both with honors from the Autonomous University of Baja California. While pursuing his PhD, Dr. Beltrán was a visiting student at the National Institute of Rehabilitation in Mexico City, and at the School of Medicine of the University of California San Diego, USA. He is professor of biomaterials science, tissue engineering, nanobiotechnology, and molecular biology at the Institute of Engineering of Autonomous University of Baja California, Mexico. He has authored several peer-reviewed articles and a book chapter, and has directed several research projects funded by grants from a number of government institutions. Dr. Beltrán has also served as a reviewer for various high impact journals such as Materials Science and Engineering C, Nanomedicine: Nanotechnology, Biology and Medicine, and Biotechnology and Biotechnological Equipment. His research interests are focused on Biomaterials, Tissue Engineering, Cellular and Molecular Biology, Nanobiotechnology, and Corrosion of Materials. beltrane@uabc.edu.mx

An additional Haifa Chemicals plant was erected at Mishor Rotem for production of KNO_3 and pure, food-grade phosphoric acid (H_3PO_4). The HCl was obtained by thermal decomposition of $MgCl_2$ brine, transported by steel pipeline from DSW.

In Mexico, innovative products for irrigation, such as drip irrigation and fertigation (irrigation with fertilizer solutions) were introduced by Netafim, an Israeli company [15].

Desalination plants: water

The innovative desalination technology for saline water (SW) is helping to alleviate the worldwide problem of potable water scarcity [15]. Desalination plants (DPs) present a high level of corrosion risk since they handle and process corrosive SW under severe operating conditions such as heat exchange, filtration, agitation, and circulation, with elevated and often turbulent flow velocities. Desalination plants therefore use, primarily, two technologies: thermal and membrane separation, known as reverse osmosis (Figure 2).

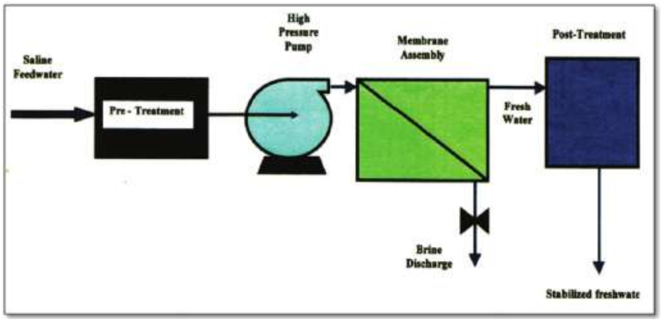

Figure 2. Flow diagram of the reverse osmosis desalination process

Selection of CRM, which include CRA, is the best method to prevent, mitigate, and control corrosion in the DP equipment, structures, and installations. The selection is a compromise between technological and economic factors.

A great variety of engineering materials are employed by DPs. Metallic materials include stainless steels, Ni-alloys, Al-alloys; plastics (PVC, PP, elastomers, rubbers); composite materials include fiberglass or carbon-fiber reinforced polyester or epoxy.

The National Autonomous University of Mexico has created a project for Multidisciplinary Investigation of Leadership and Academic Improvement, to develop desalination processes and plants in Mexico. They visit and maintain cooperative agreements with desalination organizations in Israel, Spain, and the USA.

IDE Technologies is an Israeli desalination enterprise that designs and constructs DPs worldwide, according to the build-operate-transfer (BOT) system [16].

In the last decade, Israel has solved its water problems by establishing modern DPs throughout the country as seen in Table 1 [16].

Table 1. Israel Desalination Plants

Water Cost (NIS/m³)	*Location*	*Capacity (Million m³/year)*	*Opened*
2.60	Ashkelon	120 (as of 2010)	August 2005
2.90	Palmachim	45	May 2007
2.60	Hadera	127	December 2009
2.01-2.19	Soreq	150 (expansion up to 300 approved)	2013
2.4	Ashdod	100 (expansion up to 150 possible)	September 2014

NIS, New Israeli Shekel.

The Israeli Desalination Society, with the support of the Israel Chemical Society, organizes yearly symposia on desalination science, technology and engineering.

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Energy sources: oil and gas

Oil and gas are a vital part of the energy industry in every country. Each infrastructure includes production wells, pipelines, oil refineries, marine platforms, petroleum tankers, and cryogenic ships for liquid natural gas (LNG) regasification plants [17].

In Mexico, the oil and natural gas (NG) industries, including the profitable petrochemical industry at Coatzacoalcos, is managed by PEMEX – Petroleos Mexicanos (www.pemex.com), a nationally owned complex. It includes marine platforms, service vessels, and a huge network of pipelines, pumps, and valves with a total length of 60,000 Km.

Israel has discovered NG sources near the shore of the Mediterranean Sea. Natural gas use was initiated in 2004 by the Israel Electric Corporation, and is supported by the Natural Gas Authority (www.energy.gov.il) and the Israel Institute of Energy and Environment (www.energy.org.il), both of which report to the Ministry of Energy and Water Resources.

The corrosion characteristics of NG, petroleum, and derivatives, e.g. gasoline, require the use of CRAs. Steels pipelines and drilling tools are selected in accordance with American Petroleum Institute standards (www.api.org). Submarine oil and water pipelines are made of stainless steel, the LNG vaporizer is fabricated from Al-alloy UNS A905052 and water and chemical storage tanks are produced from FRP [18].

In October 1973, the supply of petroleum to Israel was interrupted when neighboring Arab countries attacked the nation, essentially imposing a boycott. The government of Mexico assisted Israel and began sending petroleum tankers to ORL, Haifa, where the crude oil was refined and production of oil derivatives could be renewed. Groysman was the director of ORL's corrosion laboratory from 1990-2018; his experience and knowledge were published in learned articles and books.

Medical research

The medical research described here was realized by two institutes: The Institute of Engineering, University of Baja California, Mexicali and the Corrosion Research Center, Sami Shamoon College of Engineering, Beer Sheva. The focus of research in both institutions was the coating of metal alloy implants with appropriate material to improve biocompatibility with the aggressive fluids of the human body. The primary use of biomaterials, including metallic alloys, is to repair or rebuild damaged or missing parts of the human body, leading to improved quality and length of life [19].

Ti alloy passivated with TiO_2 nanotubes

A titanium alloy: Ti6Al4V was oxidized by using an anodization process to produce TiO_2 nanotubes (NTs) on its surface, with the goal of improving its corrosive resistance, biocompatibility, and tissue functionality. Anodization was performed on an electrolyte containing ammonium fluoride (NH_4F), and superoxidized water, pH = 6.8. The samples were disinfected by immersion in electrolyzed water for 12 hours.

The physico-chemical characterization of the Ti6Al4V coated with TiO_2 NTs was determined by scanning electron microscopy (SEM), energy dispersion X-ray (EDX), and atomic force microscopy (AFM). The original alloy surface and the oxidized surface are shown in Figure 3.

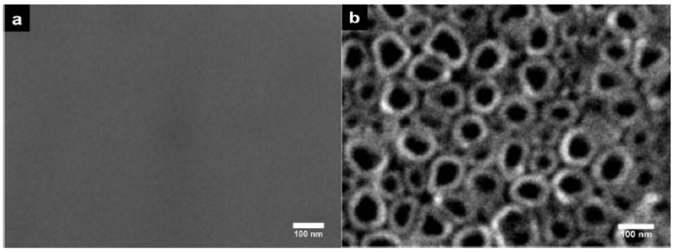

Figure 3. Comparison of the original and anodized titanium alloy. (a) Original Ti6Al4V alloy surface. (b) Ti6Al4V coated with TiO2 nanotubes by anodization.

The anodized surface improved the antibacterial effect, the adhesion and viability of osteoblast and chondrocyte, the angiogenic behavior and antifungal activity [20].

The Ixchel Medical Research Center investigated the behavior of biomaterials in the human body and in studies of water pipelines and blood vessels; the metabolism of ethanol and combustion of gasolines were compared. Au, Ag, and Ni metallic nanoparticles were considered for medical treatment of disease conditions.

Orthopedic implants coated with hydroxyapatite

The hydroxyapatite (HA), $Ca_5(PO_4)_3(OH)$, is a bioceramic widely used for coating metal prostheses, due to its ability to form strong bonds with the bones of the human body (Figure 4).

(a)

(b)

Figure 4. Pure commercial titanium coated with hydroxyapatite (a). Ti6Al4V implant parts coated with hydroxyapatite (b).

The chemical composition of HA, similar to bone composition, facilitates osteointegration – integration into the osseous tissues.

A study was performed at the Corrosion Research Center (Beer Sheva), in which Ti alloy, Ti6Al4V, and stainless steel surfaces were coated using a special computerized system, controlled by appropriate software, with the participation of students preparing their graduate theses. Electrochemical corrosion tests according to the standards of the American Society for Testing and Materials (ASTM) demonstrated that the HA coatings were corrosion resistant.

Closure

We have presented the achievements of a 30-year cooperation between Mexico and Israel, in the fields of science, technology, and engineering. The cooperation dealt with two major arenas: Israel's chemical industry and Mexico's medical research (University of Baja California).

The activities of the Israeli industrial companies: Israel Mining Industries; Dead Sea Works, Haifa Chemicals, Israel Desalination Enterprise – with its desalination plants, and the management of oil and gas reserves via the energy industry were described and illustrated.

The medical investigation led to the development of orthopedic implants with improved human body fluid compatibility and increased resistance to natural deterioration. The outcome was implants that were more durable, longer lasting, and resistant to natural deterioration, providing patients with improved quality of life.

The anodized surface of Ti6Al4V covered by TiO_2 nanotubes assisted in its antibacterial, antifungal, adhesion, and viability properties. Artificial hydroxyapatite was investigated as a promotor of osteointegration of metallic prostheses in the human body.

Acknowledgement

The authors express their gratitude to Noah Lotan for his scientific and English editing; to Petroleos Mexicanos (PEMEX), to the Corrosion Program of the Gulf of Mexico, and to the Mexican Institute of Water (IMTA) for providing information on their scientific, technological, and engineering activities; and to the academic members of the Universidad Autonoma de Baja California for professional contributions.

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Profile of Prof. Shimon Shatzmiller

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Shimon Shatzmiller (aka Shatzi) was born in 1942 to Aaron and Henia who had immigrated to the Land of Israel (Mandatory Palestine at the time) from the Romania-Hungary-Serbian triangle region (Caransebes-Lugoj) in 1929 and 1933. His father was an electrician in the cement factory in Nesher, and his mother was a housewife who volunteered in the community. Since his parents spoke German, although his mother knew the Hebrew language from being a member of the Gordonia organization in her hometown, he attended the kindergarten in a neighboring town (Nesher) where he learned the Hebrew language.

In 1948, he began his studies in the elementary school in Nesher, a school for working-class children. Initially there were only ten students in the class, but later on they were joined by child survivors of the Holocaust of various ages, who had not yet learned Hebrew. Shimon graduated from Nesher Elementary School in 1956 and was then accepted into the "Beit Hinuch" High School on Shabtai Levi Street in Haifa where he was an above-average student and excelled in science subjects. In 1960, he graduated from high school and received a high school diploma with distinction in mathematics, physics and chemistry.

In 1960, he began his studies at the Technion in Haifa in the chemistry department as part of the academic military reserve. In common with many distinguished chemists, Shimon says that he was inspired to study chemistry by his high school chemistry teacher. As part of his studies in the academic reserve, he participated in military courses and a basic officer's training course. He graduated from the Technion in 1964 with honors.

From 1964-1967 Shimon served as an artillery officer in a regular field battalion in the northern command and participated in many operational activities on the northern front before the Six Day War. Afterward, he served as an officer in the reserves.

In 1967, he was accepted to the MSc program at the Technion but was immediately called up to the army for the Six-Day War in which he served as an artillery officer on the Syrian front. After the war, he was promoted to the rank of captain and, in the same year, married Shoshana Meirovich with whom he has three children, Ronit, Noa and Yonatan.

In 1968, he completed his MSc in Organic Chemistry with Professor Eli Loewenthal on the subject: "Stereochemistry of hydrindanones and hydrindan diones," and was accepted to doctoral studies in the same group researching gibberellic acid (plants growth hormone) which was then a significant topic in the field of organic synthesis. His thesis was entitled "Attempts towards the synthesis of gibberellin."

Shimon completed his doctorate in 1971 and then joined the research group of Professor *Albert Eschenmoser* at ETH, Zurich, as a postdoctoral fellow. Those two years were a crucial period in his development as an independent scientist. When the Yom Kippur War broke out in October 1973, Shimon was in Zurich but quickly returned to Israel to fight as commander of an artillery battery on the slopes of Mount Hermon.

In 1973, he was appointed as a lecturer in chemistry in Tel Aviv University. From 1973 to 1978, he established his own research group in organic synthesis and achieved what he regards as his greatest scientific achievement, the study of the chemistry of chloro-nitrones.

After the Yom Kippur War, Shimon was one of the few officers who survived the battles on the frontline. Thus, he had to devote much time to the recovery of the army and security. When the military situation became calmer, Shimon could devote more time to his scientific work and towards the end of the 1979s he was promoted to senior lecturer with tenure at Tel Aviv University.

From 1976 onwards, Shimon was a visiting professor at the University of Heidelberg on the basis of a multi-year award from the German Max Planck Association. There, he collaborated with Professor Richard Neidlein in the field of pharmaceutical chemistry. This fruitful collaboration spawned several joint scientific and doctoral works. At the same time, Shimon improved his knowledge of biologically active substances and the activity of pharmaceutical materials on the human body.

Shimon's career has been based on three principles:
1) Scientific research and training of chemists in the field of synthetic chemistry with the aim of contributing to the pharmaceutical industry.
2) Continued activity in the field of state security and the IDF, both in planning and as a commander in the battlefield.
3) Making a personal contribution to Israel's industry and economy, through his scientific and educational activities.

Thus, Shimon has trained generations of young scientists in the field of synthetic chemistry, laying the basis of the pharmaceutical industry in Israel. For example, dozens of his students are active in Teva, Taro and other companies in the field of generics and ethical drug development. His security activities included ongoing security and training at the highest level while preparing his troops for active combat. His contribution to the economy included active involvement in the Israeli chemical industry, which led him to complete a degree in business administration.

In 1984-1990, Shimon spent a sabbatical in DuPont's molecular biology lab in Wilmington, Delaware, working with Dr. Pat Confalone in the field of bio-organic chemistry. This year was very successful as attested by Dr. Confalone:

"Prof. Shatzmiller's many excellent contributions to organic chemistry are characterized by high creativity, relevance, and importance to not only our science, but also to advances in novel medicines. In our collaborative efforts while he was a visiting scientist at DuPont, I found that this tireless, hardworking chemist seemed to virtually attack the projects, carrying out key experiments with his own highly skilled hands. His motivation and drive as a teacher is most noteworthy as is his continuing prolific contributions to the literature, a feat seldom equaled by an emeritus professor."

On his return from sabbatical, Shimon was promoted to the rank of associate professor and continued his research, partly in collaboration with DuPont in the synthesis of the drugs Ocsaar for the treatment of hypertension and Sustiva for the treatments of Aids.

Throughout his research career, Shatzmiller concentrated on developing synthetic methodologies involving unusual intermediates based on carbonyl compounds, and using this family of compounds and their derivatives for atypical synthetic procedures. From the outset of his career, he investigated the chemical use of 2-acetyl cations in substitution and non-standard cyclization reactions and developed a novel synthetic methodology based on nitrogen derivatives of carbonyl compounds. Based on these methodologies, Shimon trained many young chemists who later established themselves as independent scientists in the R&D departments of the Israel pharmaceutical industry.

In the field of peptide synthesis, Shimon has discovered amidation reactions with minimal racemization that allow for regioselectivity in the reactions of alpha and epsilon amino acids. The solid-phase-supported synthesis, and the study of the antibacterial activity of ultra-short peptides led to the discovery of pentapeptide pharmacophores as the basis for the design of new antibiotic agents. In 1989, Shimon was promoted to the rank of full colonel (IDF), with operative responsibility for the eastern Israeli front.

In 1990, Shimon received permission from Dr. Max Reis (then President of the Technion) to join Israel Chemicals Ltd (ICL) in order to resurrect and expand organic chemistry in its R&D division, Israel Mining Industries (IMI-TAMI). Shimon spent half his time in IMI-TAMI while continuing his university position. At IMI-TAMI, Shimon succeeded in introducing new ideas as well as resurrecting projects that had stagnated for a long time, such as developing the fire retardant for plastics FR-1808 and improving the production of FR-1524 (together with Bromine Compounds Ltd.). He also established a division of IMI-TAMI called Novotide in collaboration with Teva Pharmaceuticals for the production of peptides for the pharmaceutical industry.

While working at IMI, Shimon also served as President of the Israel Chemical Society (ICS) for the period 1994-1996. Prof. Ehud Keinan, current President of the ICS:

> *"In 1968, when Shatzi had just started his PhD research at the Technion with Eli Loewenthal, I started my undergraduate studies in the same Faculty of Chemistry. Nevertheless, both of us were too busy to interact, and in those days of post-1967 wartime, we were both dressed much of the time in dusty military uniforms. We became friends much later after Shatzi joined Tel Aviv University, and I joined the Weizmann Institute. I remember that in 1987, when Prof. David Ginsburg convinced me to move to the Technion, he often mentioned Shatzi as one of the best students who ever graduated from the Technion, one who could serve as an excellent role model for others. And Albert Eschenmoser of ETH shared the same view. When Shatzi established his outstanding research empire at IMI-TAMI, I used to visit him quite often, enjoying scientific discussions, mainly talking about organic synthesis. In 1997, when he decided to quit his assignment as ICS President due to extensive travel, he asked me to take over as an interim President for one year, which I accepted. That experience eventually convinced me to become elected President ten years later. I also followed with much appreciation the influential role Shatzi has had on the establishment and growth of the Department of Chemical Sciences at Ariel University. I am sure that this young university is highly grateful for his sweeping, tireless entrepreneurial spirit and friendly personality, which was well demonstrated by his achievements at Tel Aviv University, IMI-TAMI, his military service, and every other endeavor in which he was involved."*

In 1996, ICL was purchased by the Israel Corporation, then owned by the late Shaul Eisenberg and the State of Israel. Shimon was Chief Chemist at IMI at the time and was responsible for several new products at ICL, such as fuel oil additives designed to reduce air pollution and petrol consumption, which were to be introduced into the Chinese market. Shimon was summoned to China for several months to oversee a trial for the Chinese Ministry of Transport, which would potentially lead to the additives being permitted for use in all China. The plan was to produce the additives in concentrated form in Israel and set up a plant in China to dilute them. When Eisenberg died in 1997, the Israel Corporation was sold, and the project was abandoned. Shimon then resumed his position in Tel Aviv University as a full professor.

In 1998, the College of Judea and Samaria in Ariel (now Ariel University) decided to open a Department of Chemical Sciences and Shimon was appointed as its first Chair. After a year, Shimon took early retirement from Tel Aviv University and devoted himself to establishing the department at Ariel. He began by raising funds, obtaining scientific equipment, recruiting faculty, and creating the educational framework. He then turned to organizing the department's academic research and recruiting graduate students. To this end, he instigated research collaborations with Bar-Ilan University so that students could perform research in Ariel under the joint supervision of scientists from Ariel and Bar-Ilan University. To Shimon's credit, this approach was very successful, and many students completed their degrees and found employment in the Israeli chemical industry and research institutes. The accreditation of Ariel as a university is in large part due to the establishment of its high research ability, led by Shimon and his colleagues. Today, the Department of Chemical sciences is very active in teaching and research and the leadership is now in the hands of the younger generation of chemists.

Professor Michael Zinigrad, Rector of Ariel University:

> *"I met Shimon in 1998. At the time, I was the dean of the recently founded Faculty of Natural Sciences at Ariel. We were making plans for its development and were interested in inviting specialists to the college who could establish and lead new fields of teaching and research. Chemistry was one of these fields, and Shimon was the right person for this mission, arriving at the right place at the right time. The first thing that stood out in him right from the start was that he is a man of action; from the very beginning, he demonstrated a clear vision of the curriculum, organization of academic research and engagement of the student body. His extensive knowledge in the areas of organic and medicinal chemistry along with comprehensive understanding of the needs and demand of the industry with which he was closely acquainted (and which is rare among university professors) led to the expeditious creation of a research group and the beginning of teaching.*
>
> *The scientific articles published and presented at international conferences by Shimon and by his many students aim at studying the theoretical aspects of chemical processes that for the most part also bear applied value. His work and contributions are among*

the main factors that earned our institution the status of a university.

The university and his scientific work have always been, and still remain, important parts and projects of his life. Nor did the intensity of his research and his energy dwindle when he became an emeritus professor at Ariel University. The interests of the university remain at the top of his own interests. We talk frequently and he is always curious about what is new at Ariel: "Hi, this is Shatzi, I have another article (or several), I was just invited to give a keynote speech at a conference... But what's the latest at the university?"

Our Shatzi's creative activity continues and is very important for the university."

Since retiring and his appointment as Professor Emeritus in Ariel University, Shimon devotes himself to writing articles and contributing to the development of scientific research in Israel. Shoshana and Shimon donated Shimon's lab equipment to Ariel University. Due to the coronavirus pandemic, Shimon and Shoshana are in daily, but unfortunately remote, contact with their children and grandchildren. When asked what advice he would give to the younger generation of scientists, he replies, "Identify your scientific goals and follow them."

The 85th Annual Meeting of the Israel Chemical Society: February 18–19, 2020, The International Convention Center, Jerusalem, Israel*

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The Annual Meeting of the Israel Chemical Society (ICS) has a long history since its establishment in 1933. It is a well-known event in the scientific landscape of the State of Israel. These colorful gatherings of Israeli chemists usually take place in mid-February, the inter-semester break for all Israeli universities, at the end of the short rainy season. The chemistry departments of the six major research universities share the responsibility for organizing these meetings in a 6-year cycle in a constant order: the Hebrew University of Jerusalem, Technion – Israel Institute of Technology, Tel Aviv University, Bar-Ilan University, Ben-Gurion University of the Negev, and the Weizmann Institute of Science. Looking back at the ICS history of the past two decades, the Institute of Chemistry of the Hebrew University of Jerusalem has taken responsibility for organizing the 67th Meeting (2002), the 73rd Meeting (2008), the 79th Meeting (2014), and now the 85th Meeting (2020). Following a recent decision made by the ICS General Assembly, the Ariel University will join this cycle and organize the 89th ICS Meeting in 2024.

Over the past 25 years, the ICS has followed a unique tradition that has attracted much worldwide attention and interest, namely hosting high-profile delegations of distinguished scientists from top academic institutions worldwide to deliver plenary and keynote lectures. This tradition has created outstanding opportunities for many Israeli scientists, and particularly for graduate students, to interact with world-renowned chemists, thus enhancing the prospects of networking and scientific collaboration. Each visit of these delegations has created a long trail of activities, including interactive tours of students and faculty members, postdoctoral and sabbatical programs, joint research proposals, and other fruitful international programs. The first delegation on this path came from The Scripps Research Institute (1997). It continued with the California Institute of Technology (1998), the University of Cambridge, UK (1999), ETH Zurich (2000), Columbia University (2001), the University of California at Santa Barbara (2006), the Max Planck Society (2009), the Chemical Society of Japan and the Japan Society for the Promotion of Science (2010), Academia Sinica (2011), the University of California at Berkeley (2012), the University of Oxford (2014), Stanford University (2015), five universities from Texas (2016), the German Chemical Society (2017), the Royal Netherlands Chemical Society (2018) and MIT (2019). This year we had the pleasure of hosting a delegation of 10 outstanding scientists and nearly 20 graduate students from Yale University (Figure 1).

Figure 1. A traditional ICS autographed poster, displaying members of the delegation from Yale University (top two lines) and laureates of major ICS prizes

* For the full version of this abbreviated report see: https://doi.org/10.1002/ijch.202000027Ehud Keinan

The Organizing Committee included four professors from the Institute of Chemistry, The Hebrew University of Jerusalem: Shlomo Yitzchaik and Lioz Etgar as Chairpersons, Assaf Friedler, and Danny Porath. All sessions were organized by other faculty members of the Hebrew University: Uri Banin and Roy Shenhar organized the session of Nanoscience and materials, Liraz Chai – Soft matter and biophysics, Ori Gidron – Polymers and supra-molecular chemistry, Elad Gross – Catalysis and renewable energy, Zvi Hayouka – Food chemistry, Ahmad Masarwa – organic and organometallic synthesis, Noa Seri – Educational chemistry, Tamar Stein – Theoretical chemistry, Daniel Strasser – Physical chemistry, and Edit Tshuva – Chemical biology. The actual operation, including all technical aspects, administration, organization of the exhibition, promotion, etc., was carried out by the experienced team of Diesenhaus-Unitours Incoming Tourism Ltd., staffed by Anat Reshef, Tsipi Laxer and Magali Mizrahi.

The meeting venue, The International Convention Center (ICC), commonly known as Binyenei HaUma, is a concert hall and convention center in Giv'at Ram in Jerusalem. This largest convention center in the Middle East was planned by architect Zeev Rechter as early as 1949, but construction was completed in 1963. Located opposite the Jerusalem central bus and train stations at the western entrance to the town, the center houses 27 halls capable of seating over 10,000 people. Its largest hall, the Menachem Ussishkin auditorium, seats 3,104. In all, 12,000 square meters of exhibit space extends over two levels and ten display areas. Binyenei Ha'Uma is the home of the Jerusalem Symphony Orchestra. The complex has hosted many international events, among them the Eurovision Song Contests of 1979 and 1999. All plenary lectures took place in the Teddy Hall, named after the legendary mayor of Jerusalem, Teddy Kollek. The Teddy Hall and accompanying smaller lecture halls, together with a spacious lounge, exhibition, and dining areas, form a convenient complex, located on the east wing of the ICC and is accessible from dedicated road and entrance, as well as its own underground parking space. The glass floor of the Teddy lounge offers visitors an interesting perspective on an archeological site from the 1–2 centuries AD, including its two ceramic furnaces, which were used by the 10th Roman Legion that camped on the site.

The event attracted a respectable group of sponsors, including the Jerusalem Development Authority, the Weizmann Institute of Science, Tel Aviv University, Bar-Ilan University, Ben-Gurion University of the Negev, the Hebrew University of Jerusalem, the Technion, and Ariel University. The entire Yale delegation was generously supported by the President of Yale University.

The Meeting included a large commercial exhibition by providers of lab equipment, scientific instrumentation, chemicals, materials, analytical chemistry services, publishing houses, and intellectual property management. Exhibitors included Arad-Ophir Information Specialists Ltd., BioAnalytics Ltd., Meshulam Avni & Son Ltd., Pearl Cohen Zedek Latzer Baratz, Bruker Scientific Israel Ltd., Holland Moran Ltd., S. L. Moran Ltd., Rhenium Ltd., Tzamal D-Chem Laboratories Ltd., and New Road Scientific Instruments Ltd.

Over 600 participants enjoyed a diverse scientific program that included six plenary lectures and 21 parallel sessions that included 47 invited talks and 69 oral presentations. The 216 posters were equally distributed between two poster sessions. This mix of excellent lectures, colorful poster sessions, exhibitions, and other activities created a vivid atmosphere with vibrant discussions, exchange of information, and social gathering, all reflected by the collage of photographs (Figure 2).

Welcoming Reception

A joint ACS-ICS welcoming reception was held on the evening of February 17, 2020, in the Crowne Plaza Hotel, Jerusalem. The event was hosted by Prof. Luis A. Echegoyen, President of the ACS, and Lori Brown, Senior Manager, Global Outreach of the ACS. In addition to all the members of the Yale delegation, including faculty members and students, all Israeli ACS members were invited, as well as members of the ICS Executive Board and the Organizing Committee of the 85th ICS Meeting. In his welcoming address, Prof. Echegoyen greeted the audience and all ACS members who reside in Israel and expressed his desire to enhance the collaboration between the ACS and ICS.

Prof. Ehud Keinan followed up on this message, mentioning the two planned symposia co-organized by the two societies in the upcoming National Meetings in Philadelphia and San Francisco. He briefly described the history of the ICS, which was established in 1933, and pointed out that Israel's nearly 8000 chemists, 5000 chemical engineers, and 600 chemistry teachers are responsible for the fact that chemicals account for 40 % of Israel's industrial production and 25 % of its export. He also mentioned that six Israeli scientists have already won the Nobel Prize in chemistry and two of the ten presidents of Israel were scientists, both professors of chemistry.

Opening Ceremony

Prof. Shlomo Yitzchaik, Chairperson of the organizing committee, opened the Meeting and greeted the guests and participants: "Good morning everyone, on behalf of the co-chairman, **Prof. Lioz Etgar**, and the organizing committee, we welcome you to the 85th ICS meeting in Jerusalem. This two-day Meeting and exhibition, which is organized by the

Figure 2. Collage of random photos that reflect the general atmosphere of the 85th ICS Meeting. Photographs by Shlomi Amsalem

Hebrew University, will cover all fields of chemistry, including basic and applied sciences, offering outstanding opportunities for scientists, students, engineers, and teachers, to interact, exchange ideas, share new results, and create new collaborative projects. We are happy to welcome the outstanding delegation of scientists and graduate students from Yale University and ACS President Prof. Luis A. Echegoyen. I wish to explain a bit the old photos you see in the background and on the cover of the program booklet (Figure 3). They describe life at the newly established School of Chemistry in Jerusalem in the early 1920s. In 1923 Chaim Weizmann and Albert Einstein recruited Andor Fodor (1884–1968) from the University of Halle in Germany to serve as head of the School of Chemistry. The School was established two years before the establishment of the Hebrew University, 25 years before the founding of the State of Israel. We are almost at the point of celebrating 100 years of chemistry in Jerusalem. Thus, the School of Chemistry, which later became the Institute of Chemistry, is the mother of all the departments of chemistry in Israel and of most of the chemical industries. Most of the active chemists in Israel are somehow related to these pioneers, standing on the shoulders of these giants. I wish you all fruitful and productive Meeting here in Jerusalem."

Figure 3. Historical photo of chemistry at the Hebrew University: Andor Fodor and Chaim Weizmann (center) at the inauguration of the School of Chemistry in Mount Scopus (1924).

Prof. Ehud Keinan, President of the ICS, added his greetings: "Good morning everybody and welcome to the 85th Meeting of the ICS. First of all, I would like to thank all the people who made it possible. First, chairpersons Shlomo Yitzchaik, Lioz Etgar, and their colleagues from the Hebrew University, including members of the organizing committee and session organizers. There are many others who deserve our thanks, including all sponsors, the Diesenhaus-Unitours team, and administrative manager Maya Hadad for taking care of all the small details. Special thanks go to Prof. Scott Miller for our fruitful cooperation over the past year in assembling this delegation. Every single member of this wonderful team who came here from Yale, ten professors and about 20 graduate students and postdocs, all were contributing tremendously to the success of this event. Many thanks also to President of Yale University, Prof. Peter Salovey, and Associate VP for Global Strategy, Donald L. Filer, who generously supported this delegation. On a personal note, being able to launch this tradition and organize all delegations for nearly 25 years gives me enormous pride and satisfaction.

I wish to thank the President of the ACS for accepting my invitation to participate in our Meeting. It gives me much satisfaction that during my 12-year term as President I have had the privilege of hosting six ACS presidents, including Joseph Francisco (2010), Nancy Jackson (2011), Diane Schmidt (2015), Donna Nelson (2016), Bonnie Charpentier (2019) and now Prof. Luis Echegoyen. He will present the first plenary lecture. The relations between the ICS and ACS have recently intensified, as reflected by signing an agreement of collaboration between the two societies last August in San Diego. Among the many exciting initiatives are the two ACS-ICS joint symposia planned for the next ACS National Meetings, one on Polymeric Materials, and another on C1 Chemistry. Also, we have already started the process of establishing an ACS Chapter in Israel.

I want to highlight our bulletin, the Israel Chemist and Chemical Engineer (ICE), which is published twice a year under the leadership of its Editor-in-Chief, Prof. Arlene Wilson-Gordon of Bar-Ilan University. I encourage every one of you to contribute articles to the ICE on popular science, the history of science, and any topic that could be of interest to our community. I also wish to announce the establishment of the Democritus Fund within the ICS, which aims to support high school pupils in attending scientific meetings in Israel and abroad and expand their opportunities for acquiring scientific knowledge.

Continuing the historical remarks made by Shlomo, the decade of 1923–1933, was a heroic period for chemistry in the British Mandate of Palestine when the Jewish population did not exceed 100,000 people.1 Those days saw the establishment of the Technion, The Hebrew University (Figure 3), the Weizmann Institute, and the Israel Chemical Society. It is incredible that since the establishment of the ICS, we kept holding our Annual Meetings regularly, although many things have happened in the world and Israel during the past 87 years.

I would like to announce that the 86th ICS Meeting will take place in February 2021 under the Technion's responsibility, with Charles Diesendruck and Saar Rahav as chairpersons. The guest delegation will be from Peking University and the Chinese Academy of Sciences. I am also happy to announce the establishment of two new sections in the ICS, Electrochemistry, and Macromolecules. It was a pleasant surprise to realize that over 500 Israeli chemists have already expressed interest in joining the Electrochemistry Section.

Being curious about the origin of Yale's logo, I came across a fascinating anecdote, which I wish to share with you. The story starts with Rabbi Raphael Hayyim Isaac Carregal (1733–1777), who was born in Hebron, Palestine, in the Ottoman Empire. Carregal (Figure 4) became a rabbi at the age of 17 and spent much of his life as an itinerant rabbi and preacher, traveling all around the world, as if he knew that his lifespan would be short. He lectured in Constantinople (1754–1756), Curaçao (1761–1763, preaching in Spanish), Hebron (1764–1768), London (1768–1771), Jamaica (1771–1772), one year in the British colonies of North America (1772–1773), Suriname, and then Barbados (1775–1777), until his death at age 43.

Figure 4. Portraits of Rabbi Raphael Carregal (left), Minister Ezra Stiles (right), painted by artist Samuel King, and the logo of Yale University

After brief visits to New York and Philadelphia, he was hosted by the Jewish community of Newport, Rhode Island, in March-July 1773. During those six months, Carregal became a close friend of Reverend Ezra Stiles (1727–1795), a Congregationalist minister who later became the 7th President of Yale College (1778–1795). Being impressed by Carregal while attending his Purim and Passover services at the Newport synagogue, Stiles invited him to his home, and the two immediately became close friends. According to Stiles' records, they met 28 times, studied together, and discussed the Kabbalah's mysticism and even the politics of the Holy Land. Carregal tutored Stiles in the Hebrew language, to the point that they corresponded extensively in Hebrew in the following years. The letters still exist in the library of Yale University. Stiles' knowledge of Hebrew also enabled him to translate much of the Hebrew Old Testament into English.

Ezra Stiles graduated from Yale in 1746, studied theology, and was ordained as a minister in 1749; about the same time, Carregal was ordained as a rabbi on the other side of the world. As President and professor of Semitic languages, Stiles obliged all the freshmen to study Hebrew, but as this practice proved quite disagreeable to most students, Hebrew became an elective course. It is not clear if Yale's Coat of Arms, with Urim and Thummim, has shown in Hebrew letters on an open book, was designed by Stiles, or preceded his time. It was commonly accepted among scholars of his time that "Light and Truth" (in Latin, Lux et Veritas) was an adequate translation for these words. This translation was a highly appropriate motto of a college in the Age of Enlightenment and Renaissance humanism that dominated the world of ideas in Europe during that time. No wonder that this motto was later adopted also by younger universities, such as Indiana University, the University of Montana, and Northeastern University.

However, although "Light and Truth" is a beautiful phrase, it has nothing to do with the Hebrew terms. In the Hebrew Bible, the Urim and Thummim were elements of the Hoshen, the breastplate attached to the Ephod worn by the High Priest. They were connected with divination in general, and cleromancy in particular. Modern scholars agree that the High Priest possessed a set of two objects, probably two pieces of scroll marked with either Urim or Thummim, which allowed him to answer a question or reveal the will of God. Urim is derived from the Hebrew term Arrim, meaning "curses" and Thummim means innocent. Thus, the scrolls were pulled out at random by the High Priest to reveal God's judgment of an accused person, either innocent or guilty. Nevertheless, although Urim and Thummim have nothing to do with Lux et Veritas, there is no reason to change now this beautiful motto, which has been decorating Yale University for more than three centuries."

Prof. Luis A. Echegoyen of the University of Texas-El Paso, ACS President, made his welcoming remarks: "Dear members of the Israel Chemical Society, esteemed guests, and Professor Keinan, it is an honor and a privilege to be invited to speak to you today. Thank you for the opportunity to address this congress and bring greetings from the American Chemical Society members. It is my first visit to Israel, and I look forward to seeing many parts of this beautiful country after the congress with the help of several Israeli friends.

In celebration of the 85th Meeting of the ICS, please allow me to commend your success as a Society and your extensive international engagements. This is not the first time that an ACS president is participating in this event, and I am honored to not only convey greetings on behalf of the ACS in this opening ceremony but also to give a plenary lecture later today. My presence here is a continuation of the evolving relationship between the ACS and the ICS, which was formalized with a chemistry enterprise partnership agreement that Prof. Keinan signed on your Society's behalf at the ACS National Meeting

Figure 5. Honorary lifetime ICS Membership awarded to members of the Yale delegation and ACS President. Top: a group photo with the Yale delegation. Second row from left: Jonathan Ellman, Seth Herzon, Patrick Holland, and William Jorgensen. Third row: James Mayer, Scott Miller, Charles Schmuttenmaer, and Hailiang Wang. Fourth row: Craig Crews, Jason Crawford, and Luis Echegoyen.

in San Diego last year. I look forward to the great science that will be discussed here this week and the fruitful relationship and future activities between our two Societies.

In case you're not familiar with our work, allow me to give a short introduction to the American Chemical Society. We are the largest scientific Society globally, with over 152,000 members, with 20 % of them living in more than one hundred countries outside the USA. We also publish more than 50 peer-reviewed journals and are home to the Chemical Abstracts Service. The ACS is making significant efforts to become a global organization, representing chemists, chemical engineers, and allied chemical science professionals in academia, industry, and government. Our relationships with Israel are very important for us, and we are proud to be represented in Israel by our 250 members who work across academia and industry and contribute broadly to the chemical enterprise here. One of my central goals as ACS president is the internationalization of the organization. If you look at my CV, you would realize that every article that I have published has international co-authors. I do believe that international collaboration is extremely important.

The ACS seeks to be a leading partner in harnessing the power of chemistry for Earth and its people. When we seek out new partners or initiatives, we frame those conversations with the United Nations Sustainable Development Goals (SDG's) in mind. Organizations such as ACS, the ICS, universities, and industry have an opportunity to take advantage of collaboration to advance these goals. I'm pleased to report that the ICS is one of the most recent Societies to sign a joint framework agreement to collaborate to develop the SDGs as one global chemical science community. With over forty signatories to date and more expected to be added in the coming year, I look forward to seeing how we can work together to achieve these goals.

Before I conclude, I'd like to take a moment to give a quick plug to visit the ACS booth in the exposition. I'm planning to be there during the coffee break tomorrow morning to greet anyone curious about ACS, our products, and publications, so please stop by and say hi! Professor Keinan, thank you again for inviting me to beautiful Jerusalem to meet with you and join the chemical community here for what I am sure will be excellent discussions. I look forward to speaking with you throughout the next two days."

Prof. Scott J. Miller , Head of the Yale delegation: "Toda Raba and Boker Tov. I want to thank the ICS and the President of the ACS for making this event possible. It is an exciting opportunity for many of our faculty and the students. As many of you know, when Ehud suggested a delegation from Yale and invited us, I thought it was a fantastic idea, as was the case with the delegation from MIT last year. But, as you know, it is a long way from the other side of the world, and it is the middle of the semester, so I was not sure how to choose ten faculty members for the delegation. So, I thought of asking many more than ten members of our faculty. In the following two months, I was trying to back out from all these invitations, because essentially everybody wanted to join us. It was quite overwhelming, and I think that it is a real testimony to the intensity and quality of the science and specialness of the interactions we can anticipate. As for myself, I am a tremendous benefactor of the Israel-USA Binational Science Foundation, as a grantee for several years. This program has created wonderful opportunities for us to do a few things together, publish some joint papers, and get to know so many Israeli scientists here. It has been a great honor, one of the privileges of a lifetime. I am delighted to be leading this delegation and share the experience with my colleagues from Yale. Thank you very much, and I wish all of you a couple of exciting days of science together.

The opening ceremony was concluded by awarding every member of the Yale delegation and Prof. Luis A. Echegoyen, with a lifetime honorary ICS membership (Figure 5).

The ICS Awards Ceremony

Following the ICS tradition, all prizes were awarded at the Awards Ceremony (Figure 6), which took place in the afternoon of February 18, or during the Gala Dinner the same evening.

The 2019 ICS-Uri Golik Prize for Excellent Graduate Student was awarded to **Mr. Netanel Shpigel** of the Department of Chemistry, Bar-Ilan University. His research under the supervision of Prof. Michael Levi and Prof. Doron Aurbach focuses on the electrochemistry of batteries and supercapacitors and, in particular, on the development of a new analytical methodology based on advanced techniques, such as piezo-electric sensing and electron microscopy. He has applied electrochemical quartz crystal microbalance with dissipation monitoring for the characterization of electrodes during their operation.

The 2019 ICS Prizes for Excellent Graduate Student were awarded to 7 students, one from each research university.

Hadas Alon of Bar-Ilan University specializes in the manipulation of surfaces using molecular chemistry, under the supervision of Prof. Chaim N. Sukenik and Prof. Doron Naveh. Her PhD research focuses on surface chemistry on silicon and 2D materials, combining spectroscopic and electrical characterization. Her work on various kinds of surface modifications, including doping of graphene, has been published in high impact journals such as ACS Nano.

Roi Asor of The Hebrew University discovered the energy landscapes and assembly pathways of Hepatitis B capsids, as well as the assembly and disassembly mechanisms of wild type simian vacuolating virus 40, under the supervision of Prof. Uri Raviv. These processes were monitored by time-resolved X-ray scattering methods, corroborated by transmission cryogenic electron microscopy. By integrating the theory of macromolecular self-assembly with umbrella sampling of Monte Carlo, maximum entropy, and advanced X-ray scattering data analysis tools, he determined the structures and mass distribution of intermediates as a function of time.

Or Eivgi of Ben-Gurion University carries out his PhD research under the supervision of Prof. N. Gabriel Lemcoff. He studies the development of novel selective photochemical reactions using strongly absorbing molecules, known as molecular UV filters, and their applications to organic synthesis and catalysis, especially olefin metathesis. Additionally, he studies the development of new photoswitchable ruthenium phosphite complexes for photoinduced olefin metathesis.

Figure 6. Photos from the Award Ceremony of the 85th ICS Meeting. First row from left: Golik Prize to Netanel Shpigel (with Eran Golik and EK), Excellent Graduate Students award to Hadas Alon of Bar-Ilan University (with Chaim Sukenik and EK), Roi Asor of the Hebrew University (with Shlomo Yitzchaik and EK), Or Eivgi of Ben-Gurion University (with Gabriel Lemcoff and EK). Second row: Ori Green of Tel Aviv University (with Arkadi Vigalok and EK), Dvir Harris of the Technion (with Timor Baasov and EK), Hisham Mazal of the Weizmann Institute (with Gershom Martin and EK) and Diwakar Kashyap of Ariel University (in his absence, with Hanan Teller and EK). Third row: the Adama Prize for Technological Innovation to Gabriel Lemcoff of Ben-Gurion University (with Itsik Bar-Nahum, Chief Chemist of R&D at Adama and EK), the Amir Shahar Prize for Excellence in Administrative Management to Dr. Moshe Ben-Tzion z"l of Bar-Ilan University (Dani Shahar, Shmaryahu Hoz and EK), the Dalia Cheshnovsky Prize for Excellence in Chemistry Teaching to Miriam Gellerman of the Kalai High school, Givatayim (with Ori Cheshnovsky, Dani Shahar, Dorit Taitelbaum and EK), the Dalia Cheshnovsky Prize for Outstanding Young Teacher to Yigal Linkovsky of the Ben-Zvi High School, Kiryat Ono (with Ori Cheshnovsky, Dani Shahar, Dorit Taitelbaum and EK). Fourth row: the Itan Peled Prize for Excellent Chemistry Project to Maya Toybenshlak of the Branco Weiss Qiryat Hinuch, Mazkeret Batya (with Nehama Peled and EK), the Itan Peled Prize to Uriya Simon of Bnei Dror High School (in his absence to Uriya's parents with Nehama Peled and EK), the NCK Prize for Outstanding Medicinal Chemist to Timor Baasov of the Technion (with Ann-Christina Lange, senior diplomat acting as the Innovation Attaché at the Embassy of Denmark and EK), the Green Chemical Industry Prize to ADAMA Ltd. awarded to Dr. Avihai Yacovan, Head of Global Chemical R&D at Adama (left) and Hadran Olami, Neot Hovav Site Manager (middle). Photographs by Shlomi Amsalem.

Ori Green of Tel Aviv University carries out his PhD research under Prof. Doron Shabat. He obtained his BSc degree in chemistry from Tel Aviv University (2013) and MSc in organic chemistry (2015) in the same group. His research deals with the development, design and synthesis of novel chemical tools relevant for biological applications, focusing on chemiluminescent molecular probes capable of detecting and imaging relevant biological markers. He has published in ACS Cent. Sci., JACS, Angew. Chem. and other journals, including three patent applications.

Dvir Harris of the Technion carries out his Ph.D. work under the supervision of Prof. Noam Adir, focusing on the structure and function of cyanobacterial photosynthesis from the perspective of its light-harvesting antenna, known as the phycobilisome. He tries to identify the structural origin of the orange carotenoid protein (OCP). Based on his structural results emerging from mass spectrometry combined with bioinformatics, he was able to suggest a model for the overall assembly of the phycobilisome-OCP complex. A second major thrust of his research is taking advantage of the extraordinary energy transfer efficiency in the phycobilisome to produce a bio-based device.

Diwakar Kashyap of Ariel University received BSc and MSc degrees (2013) in nanotechnology from the University of Rajasthan, India, working on electrolyte material for a low-temperature solid oxide fuel cell. In 2015, he joined the fuel cells and electrochemistry group as a PhD student under Prof. Alex Schechter, working on the development of an efficient catalyst for the electro-oxidation of dimethyl ether and methyl formate, which was recently commercialized by an Israeli company. He has published 12 research papers in leading journals and three international patents.

Hisham Mazal of the Weizmann Institute received his BSc degree in Biotechnology Engineering with distinction from the ORT Braude College of Engineering. During his undergraduate studies, he did an internship at the Department of Pharmacology and Physiology at the University of Rochester, NY, USA. He joined the group of Prof. Gilad Haran for a direct track PhD at the Department of Chemical and Biological Physics. He helped develop a tool that allows researchers to observe and measure individual enzyme dynamics during their active cycle on the microsecond timescale. Using this tool, he demonstrated the involvement of ultrafast conformational dynamics in allosteric regulation of ClpB, a complex protein machine that rescues aggregated proteins. Hisham received the John F. Kennedy Award of the Weizmann Institute for his outstanding PhD research.

The 2019 ICS-Adama Prize for Technological Innovation was awarded to **Prof. N. Gabriel Lemcoff** of the Ben-Gurion University of the Negev for his pioneering and ground-breaking work on light-induced catalytic olefin metathesis and 3D printing of polymers. Lemcoff's research interests span the fields of organic chemistry, organometallics, and polymer chemistry. He specializes in the development of novel latent ruthenium catalysts for olefin metathesis and new functional macromolecular structures. He has pioneered the single-chain collapse of polybutadiene-like polymers by organometallic linkages. During the past decade, his group has developed latent olefin metathesis catalysts for several applications, including chromatic orthogonal sequences, divergent photochemical syntheses, and additive manufacturing of ROMP-derived polymers. One of their main breakthroughs in light-induced olefin metathesis was the discovery that S-chelated ruthenium benzylidenes could be activated by irradiation with UV-A light. They have developed a variety of different S-chelated and phosphite ligated ruthenium catalysts to advance the stereolithographic 3D printing of polydicyclo-pentadiene and derivatives.

The 2019 ICS-Amir Shahar Prize for Excellence in Administrative Management was awarded to **Dr. Moshe Ben-Tzion z"l** of the Department of Chemistry, Bar-Ilan University, for his dedication and creativity in multiple administrative tasks, including the evaluation and acceptance of new students, advising students and lecturers on teaching matters, managing and updating the curriculum, as well as managing the computing services and internet website. The prize was sponsored by Dani Shahar of BioAnalytics.

Ehud Keinan invited Prof. Shmaryahu Hoz of Bar-Ilan University to receive the prize on behalf of the Ben-Tzion family, explaining the unusual circumstances: "On the morning of October 6, 2019, I called Moshe Ben-Tzion at his home to let him know that he had been selected to receive the Shahar Prize. He was very happy, only apologizing for some hearing problems. By the end of December, he was hospitalized for various problems but expressed his desire to attend the ICS Meeting. At that time, I didn't know about his advanced cancer. Ten days ago, I was informed by Prof. Hoz that Moshe's situation had worsened rapidly, and he is already in a partial coma. I proposed to hold a private award ceremony at his bedside. Six days ago, as soon as I received consent from Moshe's family, we held a small ceremony in the Beilinson Hospital. I was moved and rewarded by the few happy moments Moshe and his wonderful family gained during that event. Starting with a quasi-coma situation, Moshe gradually turned excited and energized. He was able to read the entire certificate, firmly hold it for the photo, and even shook my hand. Unfortunately, Moshe passed away three days later."

Prof. Shmaryahu Hoz responded: "On behalf of the Ben Tzion Family and the Department of Chemistry at Bar-Ilan University, I would like to thank Udi (Prof. Ehud Keinan) for a heart-moving act. When I informed Udi about Benz's situation (Dr. Ben-Tzion) and the real possibility that he would not make it to the conference, he immediately expressed his desire to come and present Benz with the award at the hospital. I told Udi that it might not be worth the effort because Benz had already lost interest in the outside world. The family had the same feeling. However, I asked his son Ami to check it out with his father. Much to our surprise, Benz, who could not really talk, keyed in the word "YES." Udi came all the way from Haifa to the Davidoff Oncology Center at Beilinson Hospital, and, in the presence of the family, a mini award ceremony was conducted. Thank you, Udi, for bringing a ray of light, a sense of pride, and something good that Benz could hold on to – in the last two days of his life. Thank you, Udi, for a great humanitarian deed."

The 2019 ICS – Dalia Cheshnovsky Prize for Excellence in Chemistry Teaching was awarded to two outstanding high school teachers. **Miriam Gellerman** of Kalai High School, Givatayim, received the prize for 50 years of teaching chemistry, for professionalism, dedication, and creativity, for introducing new teaching methods and innovative pedagogy, paying attention to every student, every hour, with great patience and a pleasant manner. **Yigal Linkovsky** of the Ben-Zvi High School, Kiryat Ono, received the Prize for Outstanding Young Teacher for his great dedication, professionalism, originality, and creativity in chemistry teaching, for creating a unique and interesting environment for students, for activities beyond classroom hours and increasing demand for chemistry in the School.

The 2019 ICS Itan Peled Prize for Excellent Chemistry Project was awarded to two outstanding high school pupils. **Ms. Maya Toybenshlak** of the Branco Weiss Qiryat Hinuch, Mazkeret Batya, received the prize for "Characterization of intermediate states in redox reactions of organic molecules." The project was carried out under the supervision of Dr. Raanan Carmieli at the Weizmann Institute of Science. **Mr. Uriya Simon** of Bnei Dror High School received the prize for "Green rocket fuel." The project was carried out under the supervision of Jacky Ben Yaish at IDE Technologies.

The 2020 NCK Prize for Outstanding Medicinal Chemist was awarded to **Prof. Timor Baasov** of the Schulich Faculty of Chemistry of the Technion for developing new aminoglycosides as therapeutic agents for the treatment of genetic diseases caused by stop-codon mutations. One of his group's most significant goals has been the development of safe, non-toxic aminoglycoside (AGs) drugs. They have designed generations of new AGs that are more effective and less toxic than commercially known antibiotics. They have further developed AG compounds that can overcome genetically inherited diseases induced by the presence of stop-codon mutations. Their new AGs can allow the ribosome to "read-through" the mutation and translate the entire protein, thus alleviating diseases like cystic fibrosis and Usher's syndrome. Baasov's remarkable achievement, supported by an NIH grant, eventually led to the establishment of Eloxx Pharmaceuticals in the United States and Israel. One of his compounds, ELX-02, is already in clinical phase 2 trials against stop-codon mutations in cystic fibrosis and cystinosis diseases. Other AGs were found to be effective for Leishmania's treatment, a persistent parasite found in many places around the world, including Israel. Amongst his inventions are bi-functional AGs, which are designed to combat resistant strains of bacteria and his innovative concept of catalytic antibiotics.

The 2019 Tenne Family Prize in memory of Lea Tenne for Nanoscale Sciences was announced, and the actual award ceremony will take place in October 13, 2020, during the NANO.IL Conference in Jerusalem. The prize will be awarded to **Prof. Adi Salomon** of Bar-Ilan University for her pioneering work on nanoporous metallic networks and the interaction of light with hybrid nanoscale metal-molecule systems.

The 2019 ICS Prize for the Green Chemical Industry was awarded to **ADAMA Ltd.** for developing innovative delivery and formulation technologies for active crop protection substances, thus reducing their environmental footprint, and for minimizing waste by improving chemical yields and separations, recycling and incinerating waste, reusing packaging materials, reducing emissions of air pollutants and using clean energy. ADAMA Ltd. is one of the world's leading crop protection companies that provides farmers with effective products and services. With over 8,000 employees in manufacturing facilities, formulation centers, and R&D labs, it serves customers in more than 100 countries. It develops advanced active ingredients, focusing on quality, safety, and environmental aspects. Considerable efforts have been invested in advanced formulations, delivery, and targeting technologies that are based on a better understanding of the mechanism of action of each product. The efficient delivery of active ingredients reduces their required doses, diminishing their footprint on the environment and in the food chain, and minimizing ecological damage.

Gala Dinner and ICS Awards

Over 100 distinguished guests attended the Gala Dinner, which in the long tradition of the ICS is the occasion for awarding the major ICS prizes (Figure 7). For many people,

Figure 7. Collage of photos from the gala dinner and award ceremony of the 85th ICS Meeting. Photographs by Shlomi Amsalem

this award ceremony has been the most moving and exciting part of the entire conference.

The 2019 ICS Gold Medal was jointly awarded to two laureates, **Prof. Gil Navon** of Tel Aviv University for his outstanding lifetime contributions to Magnetic Resonance in general and biomedical NMR and Magnetic Resonance Imaging in particular; and **Prof. Jacob Klein** of the Weizmann Institute of Science for his transformative contributions to the understanding of soft and liquid matter under confinement, such as entangled polymers and frictional processes in living systems.

Prof. Gil Navon responded: "First of all, I would like to thank the Awards Committee for choosing me for the ICS Gold Medal. The prize in chemistry is especially dear to me since chemistry was my first love. In my high school years, I had a small laboratory in my back yard doing chemistry experiments.

Owing to chemistry, I have had many exciting moments in my life. My first publication was not related to my PhD thesis. It was the discovery of contact charge-transfer complexes of halide ions and molecular oxygen in solutions. Among these exciting moments, I would like to mention the finding, with Norman Sutin, that the quenching of the phosphorescence of ruthenium bipyridyl was accomplished by electron transfer and not by energy transfer as was thought before. This laid the groundwork for the development of photovoltaic cells.

The application of physical chemistry to biology has been my favorite subject and has led to many exciting moments. One of them is the first-ever observation of NMR in living cells. This was done in the Bell Laboratories. It was highly rewarding observing how NMR can provide fingerprinting of cancer cells and verifying Mitchell's chemo-osmotic hypothesis of oxidative phosphorylation (which eventually received the Nobel Prize). And all these were done by observing, in real-time, by phosphorus NMR, when oxygen is supplied to bacterial cells with simultaneous generation of pH gradient and ATP formation. All the developments were accomplished, of course, with my students and collaborators. But I would like to mention one of them that helped me in the development of the double quantum filtered NMR and MRI. It is Uzi Eliav, who sadly passed away a few months ago.

Today I am very enthusiastic about the development of a new method for diagnosis of breast cancer by chemical exchange saturation transfer MRI, which I am working on with Michal Rivlin. In fact, the technique is already being tested in cancer patients in Sheba Medical Center. Finally, I would like to thank my wife, Ruth Navon, who also happens to be my life-long best friend, for her support throughout all these years."

Prof. Jacob Klein responded: "I would like to thank the Israel Chemical Society for choosing me for this award. Having sat on many prize committees, I realize full well that there are always several worthy candidates, any of whom could justifiably be chosen, and so I feel both appreciative and humble at the same time, and, needless to say, greatly honored by this recognition. I remember the feeling I had exactly ten years ago when I received the ICS Prize of Excellence from the same President of the ICS, Prof. Ehud Keinan (Udi). I want to express my appreciation of Ehud Keinan, under whose leadership for the past 12 years the ICS has contributed strongly to raising the level of awareness, activity, and success of chemistry in Israel at all levels: from schools through to the highest levels of cutting-edge research.

Most prominently, I want to express my thanks to the many students, postdocs and collaborators, whose work with me is directly responsible for my being honored on this occasion. Seventy-eight students and postdocs, including my present group, have worked with me over the years. Of these, 29 are currently tenured or tenure-track academic faculty in Israel and abroad: five in Israel, 17 in Europe, three in North America and China, and one in India. The others are all in industry, mostly in Israel. Many of them have achieved their high level of distinction, including two Fellows of the Royal Society, one L'Oreal Women in Science Laureate, and a primary European university president.

The achievements and success of all my former students and postdocs, who are my academic 'children,' and who in turn have 'begat' their own academic 'children' (my 'grandchildren'), are the source of most exceptional pride of my scientific career. I must also mention my early academic mentors and scientific heroes: David Tabor and Sam Edwards, both from the University of Cambridge, and Pierre Gilles de Gennes of the Collège de France in Paris; all of them have passed away, unfortunately. I can only hope that I have given my coworkers a similar level of inspiration to that which these great scientists infused in me.

I will not talk about my scientific work in detail, but I would like to mention one early experience, which has remained strong in my memory. In 1979, as an independent researcher shortly after my PhD, I was using my self-designed Surface Forces Balance at the Weizmann Institute to measure for the first time the forces between polymer molecules attached to surfaces. The results were strange – the surfaces moved towards and away from each other, at separations of just a few nanometers, in a reproducible but (at first) incomprehensible manner. Eventually, after a couple of hours, I worked it out: I directly measured the van der Waals attraction between the polymer molecules across the solvent in which they were dissolved. When I realized this – the first-ever direct measurement of attractive forces between molecules, many years before the advent of atomic force microscopy – I was so excited that I could not continue the experiments. I just had to get out of the small, windowless lab and walk around for about half an hour to calm down. That 'Eureka' moment has stayed with me for over four decades; happily, it was not the only such moment in my career – though it was perhaps the most intense – and reminds me that such experiences are among the many rewards of a life in scientific research.

Finally, if there is one 'fixed point' in my career, which has spanned different continents, laboratories, and projects over some 45 years, the person whose encouragement, care, good advice, and love contributed so much to any achievements I may have had, it is my wife, Dr. Michele Klein, sitting here. Thank you all very much."

The 2019 ICS Prize of Excellence was awarded to **Prof. Michael Urbakh** of the Tel Aviv University School of Chemistry for his discovery of the chiral-induced spin selectivity (CISS) effect and for his work on the interaction of electrons with bio-molecules; and to **Prof. Ashraf Brik** of the Technion Schulich Faculty of Chemistry for his pioneering contributions to the chemical synthesis of modified proteins, which led to a better understanding of their properties and function in health and disease.

Prof. Michael Urbakh responded: "Dear ICS Prize Committee and organizers of the ICS meeting, I am very proud and touched to receive this prestigious award. During the last two decades, my group has focused on theoretical and numerical studies of frictional properties at the nanoscale. Friction is one of the oldest phenomena examined and used by humankind, and it has diverse implications in many scientific and technological fields. We are trying to understand how friction forces depend on the structure and chemical properties of contacting surfaces and on interactions with embedded molecules (lubricants). Our ultimate goal is to find efficient ways to tune friction in a controllable way. I find friction problems fascinating. They combine fundamental questions important for chemistry, physics, and even mathematics, with challenging applications. This makes the study of friction so attractive to my students and me. Until now, the field of friction was not in the focus of the Israel Chemical Society. I consider this award a recognition of the field of friction by the Israel chemical community. I would especially like to thank my wife and my sons for supporting me throughout this wonderful scientific journey and showing me unconditional love and understanding."

Prof. Ashraf Brik responded: "I wish to start by thanking the Yale delegation, which made this Meeting so enjoyable, the organizers of the scientific program, friends, students, and faculty members from the different universities us in this special evening. I also wish to thank the President of the ICS, Prof. Ehud Keinan (Udi), who has been leading this Society in an extraordinary way since 2008 and brought it to an outstanding level. Since Ehud was also my PhD advisor, these are exceptional moments to me, standing here and receiving this award.

I wish to share with you some of my backgrounds and give you a glimpse of what I went through to reach this moment. I grew up in a family from the Arab Society in Israel, a very humble family consisting of six sisters, four brothers, and very loving parents. Yet, none of my brothers and sisters made it to higher education. I never had a single role model from my surroundings who had made the long way to academia. I often think to myself, trying to understand how come I was different and went through this path! Indeed, I remember how much I loved chemistry when I was in school. Yet, when I try to dig deeper into my thoughts and find out how this love relation all started, I find no answer. The fact that I grew up in a small village in northern Israel, spending so much time during my childhood playing in the fields and mountains surrounding the village, made me perhaps wonder about the many things that I saw and played with, such as the colorful soils, rocks, rusty metal and more.

This background and passion for chemistry keep me busy thinking about how to bring these experiences to our kids and school students and inspire them to love science in general and chemistry in particular. If I take myself as an example, I do a lot in this regard by lecturing in schools about my research and my story and love for chemistry as the main reason for my success, if I may say. I am a few days away from signing a contract with a local publisher for distributing my book "Chemist's Musical Notes," which I have written in Arabic during the past three years. This book aims to share my experience and knowledge in science and chemistry in particular and personal insights with ordinary people, high school and university students at all levels. I have raised a reasonable budget that will enable me to distribute the book for free to as many students as possible.

My academic journey started at Ben-Gurion University, where I received my undergraduate education, then MSc with Nizar Haddad at the Technion and a PhD with Udi, who took me over to Scripps in California, which was a fantastic experience for me. I learned so much during those nine incredible years at Scripps with Udi, Phil Dawson, and Chi-Huey Wong. Then I moved back to Ben-Gurion University, where I received tremendous support from many friends and colleagues. My move to the Technion, five years ago, has become an outstanding experience due to the wonderful colleagues I have in the Schulich Faculty of Chemistry. I wish to thank them all and appreciate the many colleagues from other universities and scientific collaborators for their great support and friendship.

I wish to end by thanking the fantastic, past, and current students in my laboratory, particularly Dr. Guy Kamnesky, the senior scientist in my laboratory. Of course, I wish to thank my beautiful family, in particular my two children, Jude and Rayan, who are making my life so enjoyable and meaningful. Thank you all."

The 2019 Honorable Member of the ICS Award was presented to **Prof. Abraham Nudelman** of Bar-Ilan University for his multifaceted achievements in medicinal chemistry and for educating many of Israel's leading medicinal chemists.

Prof. Abraham Nudelman responded: "I would like to take this opportunity to tell you a story that demonstrates the life of a medicinal chemist. Long ago, the pharmaceutical company Bristol Myers marketed a very potent antibiotic. When the patent was about to expire, they found that the active ingredient had changed its crystallographic form. This is a quite common phenomenon in medicinal chemistry. They found that the new form had some improved properties and therefore decided to patent the new crystals. When the patent on the old crystals expired and became a generic compound, they came up with a new patent on the new crystalline form. Several European companies started marketing the generic form.

Bristol Myers examined those generic compounds and found that they all had the new crystalline form. So, they sued those companies for infringement of their patent. Those companies responded that there was no such thing as old and new forms. Since the new form is more stable than the old one, nobody could produce the old crystalline form anymore, probably because all the laboratories were contaminated with the new form's microcrystals. To solve the legal problem, Bristol Myers decided to look for a country where this drug was not marketed and found that Israel was such a country. Bristol Myers' attorney approached me and asked if I would repeat the procedure described in their old patent and get the old crystalline form. I asked for the rationale, but he said that he could not tell me at that point. So, I made the compound and submitted it to powder X-ray crystallography. I repeated the procedure five times, and in all of them, I obtained the same crystals, all of them of the old form.

The Bristol Myers attorney became extremely happy, flew my wife and me to New York, and gave us royal treatment in the best possible hotel and restaurants. Then he took us to Washington DC and again put us in a fancy hotel. When I appeared as a witness in court, I met one of the European companies' attorneys. He was a Hasidic Jew from Brooklyn who promised to obliterate me in a cross investigation. After I finished my testimonial, he realized that they had lost the case. He stood up and greeted me in the Hebrew "Yishar Coach," meaning "well done." Bristol Myers eventually won the case, which saved them about $200 million every year. I wish to conclude by thanking Ehud and the ICS for the great honor and the many members of my family who joined me in this special evening."

The 2019 ICS Excellent Young Scientist Prize was awarded to **Prof. Charles E. Diesendruck** of the Schulich Faculty of Chemistry, Technion, for his studies on tuning the mechanical response of polymers at the molecular level.

Prof. Charles E. Diesendruck responded: "Thanks Udi, good evening, everyone. This award is a great honor to me, and I have many people to thank. First of all, I need to thank my teachers and my parents – both real and academic. Gabi Lemcoff, who also received an award today – making him proud is one of the driving forces in my research. I have also to thank my postdoc advisors Jeff Moore from UIUC who, together with Prof. Nancy Sottos and the late Prof. Scott White showed me not only what real collaboration is, but that chemistry is the central science not only to biology and medicine but also in mechanics and the deepest aspects of materials, opening my eyes to a very unoccupied and yet important field of chemistry. I have to thank my partner in life Liana, who not only sacrificed a lot for me to have an academic career but also helps me every day – sometimes as a thesaurus, sometimes just reading papers or grants or just talking to me about how to deal with day-to-day problems in the lab. I thank my colleagues at the Technion for their support and excellent environment for the science they provide. And finally, my students and coworkers – most of my current group is here today, and it is nice to share this award with them, who do all the work. I can state that this award is their success, and without them, nothing would have happened.

Instead of talking about my science, I wish to say a few words about this award. Aviv Amirav, Sason Shaik, and Lia Addadi were the first three young scientists to receive this award. It is hard to think about anything bad that starts with these three names. Doron Pappo, Sharon Ruthstein, and Roey Amir were the last three winners, a bit less famous, but yes, I expect no less of them. We have many excellent chemists in Israel, not all of them received this award, but if you go through the list of the people who did receive this award, they are all excellent, and all are leaders in their fields in the world, all people that inspire me and that I look up to. I've been fortunate to have received several important awards in these past few years, most of them telling me that I'm doing a great job, but this award is different. This award is saying, "you are OK, but we expect a lot more from you. We expect you to get to the level of Aviv, Sason, Lia, and all the other names on the list." So, thanks to the committee for choosing me, I can feel the heavyweight on my shoulders, and I look forward to meeting your high expectations in the future."

Closing Ceremony

Chairpersons Shlomo Yitzchaik and Lioz Etgar announced the four equal Poster prizes, all sponsored by BioAnalytics. They awarded them to the winners: Nadeem Eghbarieh of the Hebrew University, Tomer Burshtein of the Technion, Maya Hadar of Tel Aviv University, and Eyal Merary Wormser of Ben-Gurion University.

Ehud Keinan made some concluding remarks: "I wish to conclude this Meeting by thanking the many people who are responsible for this highly successful Meeting, which enjoyed excellent scientific content and good attendance, particularly when considering the unavoidable conflict of dates with another big meeting – the ILANIT congress in Eilat. We had some concerns about moving away from our traditional venue in Tel Aviv to this venue in Jerusalem. Many people in our community still believe that Jerusalem is less accessible than Tel Aviv. Based on the good experience we had now in the ICC, we may consider returning to this site. I wish to thank the chairpersons, Shlomo Yitzchaik and Lioz Etgar, and the organizing committee who have done an outstanding job with the scientific program. I would like to thank the organizing company, Diesenhaus-Unitours, mainly Anat Reshef, Tsipi Laxer, and Magali Mizrahi. All the members of the delegation from Yale deserve special thanks, and Scott Miller, in particular, who was so helpful and cooperative all the way. I am so proud that we managed to bring in so many great scientists and outstanding graduate students. Based on our previous experience, this delegation will leave a long trail of collaborations and scientific relations between Israeli chemists and people from Yale, sabbatical, postdoctoral programs, joint research plans, and many other good things. I also thank ACS President Luis Echegoyen for coming over. I know it was not trivial for him to dedicate more than a week to visit Israel, and we appreciate that, and I am looking forward to meeting you again next month in the annual Meeting of the ACS in Philadelphia. This is not the first time we have collaborated with the ACS and certainly not the last. The ICS-ACS relation will intensify in the following years. I wish to thank the new Administrative Manager of the ICS, Maya Hadad, a natural problem-solver. I thank Maya personally and consider myself very fortunate to have had her in this position over the past several months, as she has made my life so much easier. Finally, I invite all of you to the 86th Annual Meeting of the ICS, where we'll host a large delegation from Peking University and the Chinese Academy of Sciences. It will take place in February 2021, under the responsibility of the Technion. Thank you all for coming and for actively contributing to this successful Meeting."

Scott J. Miller concluded in the name of the Yale delegation: "I wish to reiterate and express many thanks, Toda Raba. On behalf of the delegation members, I wish to echo their thanks to the organizers and to all of the faculty and all of the students and postdocs here in Israel who actively participated in the lectures and poster sessions and asked excellent questions. It really created an electric intellectual environment, and I fully agree with Ehud about the future consequences of this Meeting. I am absolutely certain that all kinds of collaboration, interaction, and discussions, stimulating many ideas and new research directions will follow for many years to come. I want to thank Luis Echegoyen of the ACS and Ehud of the ICS for their collaboration, which made it possible for all of us to come together, and I look forward to seeing much more in the future. I have noticed that at the end of every special time together, people say farewell to one another, using the Hebrew word, Le'hitraot, which means not only goodbye but also "we will see you again," and this is a sentiment that is really overwhelming for all of us. Thanks again to everybody here for our opportunity to serve as the Yale delegation. I think our colleagues at Peking University and the Chinese Academy of Sciences are extremely lucky, and they have many things to look forward to. Le'hitraot."

The Israel Chemical Society
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