Exciting New Directions in Electrochemistry: Honoring 2008 Wolf Prize Recipient Allen J. Bard

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Guest Editorial

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Exciting New Directions in Electrochemistry: Honoring 2008 Wolf Prize Recipient Allen J. Bard

This issue of the Israel Journal of Chemistry is dedicated to Allen J. Bard, 2008 recipient of the Wolf Prize for single-molecule electrochemical detection and the development of scanning electrochemical microscopy and nanoscopic imaging. The highly distinguished prize was presented to A. J. Bard by Israel's President, Mr. Shimon Peres, in a special ceremony held in the Israeli Knesset. This is the most recent in a series of international recognitions of the scientific activity of A. J. Bard. Some of his other distinguished awards and prizes include the Carl Wagner Memorial Award (The Electrochemical Society, 1981), the Fisher Award in Analytical Chemistry (American Chemical Society, 1984), the Charles N. Reilley Award (Society of Electroanalytical Chemistry, 1984), the Henry Linford Award (The Electrochemical Society, 1986), the Willard Gibbs Award (American Chemical Society, 1987), the Olin-Palladium Medal (International Society of Electrochemistry, 1987), the Analytical Chemistry Award in Electrochemistry (American Chemical Society, 1988), the Luigi Galvani Medal (Societá Chimica Italiana, 1995), the National Academy of Sciences Award in Chemical Sciences (in 1998), the Priestley Medal (American Chemical Society, 2002), the William H. Nichols Medal (American Chemical Society, 2004), and the Welch Award in Chemistry (The Welch Foundation, 2004). A. J. Bard was named Fellow of the National Academy of Science in 1982, Fellow of The Electrochemical Society in 1990, and Fellow of the American Chemical Society and Royal Society of Chemistry in 2010.

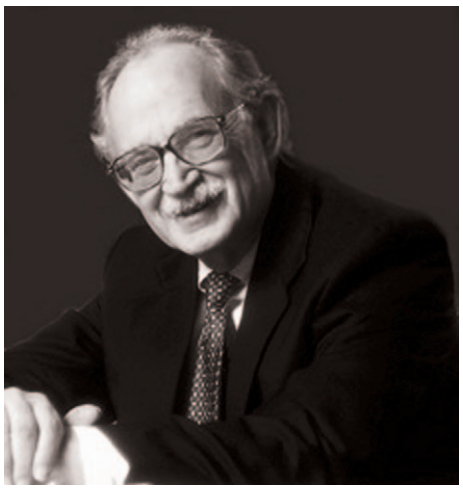

Figure 1.

Allen J. Bard has influenced, and at times shaped, the field of electrochemistry and thereby the study of interfaces for over five decades, in many different ways. It is impossible to practice electrochemistry today without resorting in some way to the fundamental principles, protocols, or electrode materials that were first introduced or made clear by Prof. Bard. The best way to get "up-to-speed" acquaintance with a new field in electrochemistry, be it an evolving or a conventional technique, or material research, is through his edited series and books. Every electrochemistry teacher is—or had better be—acquainted with his comprehensive textbooks (most notably, *Electrochemical Methods*, coauthored by his former student, L. R. Faulkner). His 300 students and scholars disseminate around the world the "Bard's Lab" belief in Electrochemistry in the Service of Scientists and Science. For many years his industrial influence was only indirect, through insights gained by his fundamental treatise, but more recently his influence has become more direct since his instruments (the Scanning Electrochemical Microscope) and techniques (Electrogenerated Chemiluminescence immunoassays) are now widely used, and today they are an integral part of medical diagnostic practice in hospitals and activities in research institutes.

A Few Examples of Groundbreaking Scientific Contributions

We shall confine this discussion to only three major noteworthy areas, although much can be written on his other fields of research.

Prof. Bard was a cofounder of the field of electrogenerated chemiluminescence, ECL, and the first to recognize and demonstrate its analytical impact. The early fundamental work of Bard's Lab provided him with a thorough understanding of the role of organic radicals in redox processes, and over almost half a century this led to a series of more than 100 papers, in which Bard's Lab has nursed the technique from its invention through a series of

groundbreaking revelations to a mature and highly useful diagnostic technique. Among his breakthrough inventions one may note: ECL at a single electrode, introduction of $Ru(bpy)_3^{2+}$ as an ECL reagent, analytical application of ECL, ECL in aqueous solution (with Israel Rubinstein, a contributor to this special issue), and ECL for chelate–DNA interactions and for immunoassays. ECL is now widely used for immunoassays, with close to 100,000 clinical instruments in the field.

Photoelectrochemistry (PEC) at semiconductors is another example of over half a century of dedicated, uncompromising, and novel research, which started with a fundamental understanding of charge separation in excited semiconductors, continued with a visionary realization of the role of semiconductor electrochemistry in solar energy conversion, and developed through a series of breakthroughs in semiconductor photoelectrochemistry. These included: the first use of cyclic voltammetry for mapping semiconductor electrode energetics, the first report on the photo-Kolbe reaction, the first conclusive demonstration of hydroxyl radical as a reaction intermediate on TiO_2, introduction of the concept of "Fermi level pinning" at the semiconductor/liquid interface, and many other "firsts" which paved the way for PEC to reach where it stands today. In addition, Prof. Bard was the first to demonstrate titanium dioxide photocatalytic remediation, in a seminal line of research, and has seen the field grow into a vivid industry with enormous environmental implications.

More recently, Prof. Bard's research interests have been extended to probe microscopies. He realized the importance of probe microscopies soon after the invention of scanning tunneling microscopy, STM, by Binning and Rohrer, and his group was the first to implement the technique for electrochemical studies. Again, as for other fields that Prof. Bard has targeted, a series of breakthroughs were reported in the following years, including the first imaging and conductivity studies of active electrodes held under potential control and the first corrosion studies (with one of the Guest Editors of this issue), the first imaging of oxidation of HOPG, and insightful AFM probing of the diffuse double layer of electrodes with a conductive tip. These activities led to the introduction of the SECM, a field that has started with a paper detailing different ways by which electrochemical reactions can be used to probe the electrochemical activity of a local surface directly under a scanning tip probe (with one of the Guest Editors of this issue). Later work led to theoretical modeling of different modes of SECM analysis, its use for high resolution fabrication by deposition or etching (with one of the Guest Editors of this issue), and elucidation of local kinetics of biochemically- and otherwise-modified electrodes. Single molecule trapping and detection, which was demonstrated by Prof. Bard and his former post-doc and life-long colleague Fu-Ren "Frank" Fan, brought the capabilities of the SECM to an unprecedented and probably near-ultimate resolving power. An account of SECM studies of single nanoparticles is the subject of Bard's own contribution to this special issue. SECM has evolved into an active research area, and it has recently become more accessible to a wider community of electrochemical practitioners and surface scientists with the commercialization of SECM (through one of Bard's licensed patents).

For lack of space we refrain from elaborating on Bard's impact on electrochemistry under supercritical conditions and in exotic liquids, the invention of polymer reference electrodes, and his contribution to the area of modified electrodes. (Bard was the inventor of the celebrated Nafion modified electrode, and he used thiol-based self-assembled monolayers before they were formally invented by J. Sagiv—though, in Bard's words, "…we didn't recognize the possible significance of this idea at the time.") We also leave unmentioned numerous other research fields in which Bard's contributions surpass the life-time achievements of most scientists in first-class universities.

Teaching

Prof. Bard's profound interest in teaching and education is obvious to any attendee at one of his lectures. It invariably starts with a very simple background, laying the foundation, and gradually evolves to a description of the mechanistic details and cutting-edge science that only some can appreciate in full. Everyone, from the undergraduate student to the expert in the field, emerges with his own take-home message. Prof. Bard has educated over 80 graduate students and more than 190 post-doctoral fellows over the years. Over a third of those remained in academia and in research institutes, and they play a profound role in contemporary electrochemistry and surface science at large.

Papers and Dissemination of Electrochemical Knowhow

To date, Prof. Bard has to his credit some 850 published papers, 23 patents, and 75 book chapters. Prof. Bard's books and the book series he has edited span all levels of electrochemical education and practice: He coauthored the leading comprehensive textbook in electrochemistry, *Electrochemical Methods—Fundamentals and Applications* (1st edition published in 1980, 2nd edition in 2000, with L.R. Faulkner), and two books for electrochemical practitioners, *Chemical Equilibrium* (1966) and *Integrated Chemical Systems: A Chemical Approach to Nanotechnology* (1994). He co-edited the most useful practitioners' book on SECM, *Scanning Electrochemical Microscopy* with M.V. Mirkin (a contributor to this issue), in 2001, and a new book in this series is in preparation. The reactions and thermodynamic data in his edited book, *Stan-*

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dard Reduction Potentials in Aqueous Solutions (with R. Parsons and J. Jordan, 1985) are indispensible for electrochemical practitioners

Two series co-edited by Prof. Bard cover materials (*Encyclopedia of Electrochemistry of Elements*) and methods (*Electroanalytical Chemistry*). Volume 23 of the *Electroanalytical Chemistry* series appeared this year (co-edited by C. Zoski, a contributor to this issue). Recently, he has also edited, together with M. Stratmann, a comprehensive series of advances in electrochemistry (*Encyclopedia of Electrochemistry*, volumes 1–10).

Science Promotion Activities

It sounds incredible that, with all these activities, Prof. Bard has nonetheless also found the time for voluntary scientific activities. For twenty years, Bard served as the Chief Editor of the *Journal of the American Chemical Society*. He has also been active in different roles in the International Union of Pure and Applied Chemistry, IUPAC, and served as the president of IUPAC from 1991 to 1993.

Relations with Israel

Prof. Bard is a strong supporter of Israel, and has many social links to our country. Prof. Bard is a member of the academic advisory board of the Weizmann Institute of Science in Rehovot, and he received an honorary doctorate from the institute. Seven of his students came from Israel, and four of those who hold academic positions in Israeli universities contributed to this special issue.

It has been our privilege and honor to edit this special issue dedicated to Prof. Bard—or, he prefers—"Call me Al…" It represents only a glimpse of the contributions of his students and followers, whom he has educated and nurtured. We, as well as all the electrochemistry community, wish him many more years of health, happiness, and exciting electrochemistry and discoveries.

Ovadia Lev
Guest Editor

Daniel Mandler
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