I. Willner

*The author presented on this page has recently published his **35th article** since 2000 in Angewandte Chemie*: "Multiplexed Analysis of Hg^{2+} and Ag^{+} Ions by Nucleic Acid Functionalized CdSe/ZnS Quantum Dots and Their Use for Logic Gate Operations": R. Freeman, T. Finder, I. Willner, *Angew. Chem.* **2009**, *121*, 7958–7961; *Angew. Chem. Int. Ed.* **2009**, *48*, 7818–7821.

Itamar Willner

Date of birth: January 27, 1947

Position: Professor of Chemistry, The Hebrew University of Jerusalem (Israel)

Education: 1968 BSc with distinction in Chemistry-Physics, The Hebrew University of Jerusalem
1973 MSc with distinction, The Hebrew University of Jerusalem
1978 PhD with distinction, The Hebrew University of Jerusalem
1978–1981 Postdoctoral Research Associate, Department of Chemistry and the Laboratory for Chemical Biodynamics, University of California, Berkeley (USA)

Major awards: **1998** Max Planck Research Award for International Cooperation (Germany); **2001** Israel Chemical Society Award; **2002** Israel Prize in Chemistry; **2002** Member of the Israel Academy of Sciences and Humanities; **2004** Member of the European Academy of Sciences and Arts; **2005** Honorary Professor at Tsinghua University, Beijing (China); **2007** Honorary Professor at the East China University of Science and Technology, Shanghai (China); **2008** The Rothschild Prize (Israel); **2008** The EMET Prize (Israel); **2009** Fellow of the Royal Society of Chemistry (FRSC, UK); **2009** Member of the German National Academy of Sciences–Leopoldina

Current research interests: Bioelectronics related to the development of chemical means to communicate biomolecules with electrodes and to apply the systems as electrical sensors; Modification of surfaces with biomolecules for optical and sensor applications; Synthesis of conjugates of biomolecules with metal nanoparticles or semiconductor quantum dots and the use of the systems as optical sensors and as probes for intracellular metabolism; Self-organization of biomolecules, particularly nucleic acids, into programmed nanostructures that perform machinery functions, logical and computing operations, and act as templates for the construction of nanocircuitry; Modification of surfaces with functional molecular and nanoparticle systems acting as molecular machines, sensors, switching devices, and slow-release systems; Development of artificial photosynthetic systems, biofuel cells and photobiofuel cells as alternative energy sources

Hobbies: Collecting archaeological items, particularly ancient Jewish coins, and collecting paintings

If I wasn't a scientist, I would be … an art and antiquities researcher.

The secret of being a successful scientist is … to be creative and innovative, to work hard, and most importantly, to be lucky.

The part of my job that I enjoy the most is … to sit with my young co-workers and formulate a new research project, while realizing how smart and motivated they are.

My favorite subjects at school were … chemistry and physics.

When I was eighteen I wanted to be … a chemist.

When I wake up I … plan challenging experiments for my students with the help of a strong cup of coffee.

The biggest problem that scientists face is … the selection of challenging and exciting research projects that provide a solution to an important unsolved problem or generate a new concept to help mankind.

The biggest challenge facing scientists is … the development of clean alternative energy sources and the development of effective anticancer drugs.

I chose chemistry as a career because … it gives one the possibility to create something new every day and to transform a crazy idea into a viable functional system.

The most important future applications of my research are … in the field of sensors for medical diagnostics, homeland security, and environmental control (i.e., the development of alternative energy sources).

The most exciting thing about my research is … the freedom to select and formulate research projects and to see how an idea can be materialized.

My biggest motivation is … to make an important discovery that solves a fundamental scientific issue.

The best advice I have ever been given is … to use chemistry as a bridging discipline between physics and biology, and to have solid understanding in all disciplines of chemistry (Melvin Calvin).

I would have liked to have discovered … the duplex structure of DNA and the polymerase chain reaction.

How is chemistry research different now than it was at the beginning of your career?

Several major things have changed. First, tremendous advances in analytical techniques have been accomplished, which include the development of NMR, mass-spectrometry, infrared spectroscopy and X-ray techniques. These enable the precise characterization of supramolecular structures, biopolymers, nanostructures and surface-confined monolayers. Specifically, the imaging of single molecules and nanostructures by scanning probe microscopy and high-resolution electron microscopy have become standard tools in the laboratory, and these were just dreams in the early stages of my career. Second, significant theoretical and experimental advances have been accomplished by the synthesis of nanoparticles, nanotubes, or nanowires and the understanding of the unique electronic, optical, and magnetic properties of these nano-objects. This has paved the way to new research areas, particularly by coupling traditional molecules or polymers as well as biomaterials to these nano-objects to yield new hybrid materials exhibiting novel properties and functions.

Has your approach to chemistry research changed since the start of your career?

Yes. At the early stages of my research, the emphasis was on synthetic molecules as the key elements of the research, but in later studies we discovered the important functions of biomolecules in chemical systems. Particularly, the chemical modification of biomolecules with molecular or nanoparticle systems paved the way to materials of new properties and functions. This has definitely established new chemistry with exciting opportunities. Also, the visualization of single molecules by various microscopy methods introduced new tools for the routine characterization of our systems at the molecular level.

Has your approach to publishing your results changed since the start of your career?

Not really! My attitude was to publish in top scientific journals and to emphasize the quality of the results. I continue with this approach!

What do you think the future holds for your field of research?

We are extensively involved in the rapidly developing field of nanobiotechnology. This field holds great promise for future applications in sensor design, drug delivery, information processing, energy conversion, and nanomedicine. I truly believe that our research efforts will lead to high-throughput detection systems for clinical diagnostics and homeland security. I believe that we are on the way to developing DNA-based molecular machines that will rapidly detect genetic disorders, and biomarkers for various diseases and toxins. I also feel that the information encoded in biomolecules could be implemented to develop biocomputing devices for future nanomedicine. The implant of biocomputing elements into cells and their activation by triggering biomarkers are anticipated to lead to selective destruction of cells, such as tumors. Also, our pioneering study demonstrating the development of a biofuel cell element is rapidly advancing, and I foresee the application of these systems as "green batteries" and as systems that use body fluids, such as blood, as the source of electrical power for the operation of implanted devices.

Have you changed the main focus of your research throughout your career and if so why?

I was always interested in the tailoring of chemical systems in which photonic, electronic, or catalytic functions emerge from the organization of the molecular components. Although the specific targets of our research have changed over the years from artificial photosynthesis to bioelectronic and optoelectronic systems, and then to nanotechnology and nanobiotechnology, the fundamental concepts remain unchanged. We use biomaterials as active components in chemical systems and try to mimic them by artificial chemical approaches. In turn, we try to chemically modify biomolecules and introduce new functions and properties into the resulting biomaterials.

What has been your biggest influence or motivation?

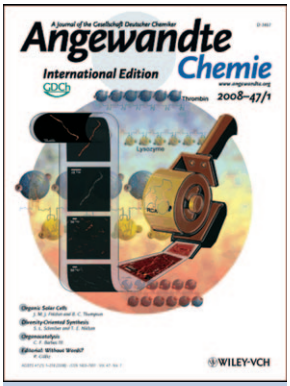
The excitement of formulating a new concept and the realization that it is experimentally achievable. Specifically, to discover a fundamental paradigm that can be developed further by other scientists and that could contribute to the benefit of mankind.

What advice would you give to up-and-coming scientists?

Success comprises three elements: The talent to formulate creative and challenging projects, hard work, and luck. So my advice would be to keep on working hard. If you have the appropriate skills and luck, the future is bright.

What is the secret to publishing so many high-quality papers?

I have been fortunate throughout the years to have extremely talented and highly motivated co-workers. I should credit them for our success.



I. Willner has been featured on the cover of Angewandte Chemie:
"Increasing the Complexity of Periodic Protein Nanostructures by the Rolling-Circle-Amplified Synthesis of Aptamers": Z. Cheglakov, Y. Weizmann, A. B. Braunschweig, O. I. Wilner, I. Willner, *Angew. Chem.* **2008**, *120*, 132–136; *Angew. Chem. Int. Ed.* **2008**, *47*, 126–130.

My 5 top papers:

1. "Bioelectrocatalyzed Amperometric Transduction of Recorded Optical Signals Using Monolayer-Modified Au-Electrodes": I. Willner, M. Lion-Dagan, S. Marx-Tibbon, E. Katz, *J. Am. Chem. Soc.*, **1995**, *117*, 6581–6592.
   This paper is a key study that describes the functionalization of electrode surfaces with photoactive or electroactive molecular or protein monolayers. The paper describes the photoswitching of biomolecular functions and the amplified readout of the photoswitchable functions of the biomolecules. This study guided our research on electrical wiring of redox proteins with electrodes in monolayer configurations, and was the basis for developing our research activities on photoswitchable biomaterials and molecular systems on surfaces. This study has established new directions in the area of molecular and biomolecular optoelectronics.
2. "Plugging into Enzymes: Nanowiring of Redox Enzymes by a Gold Nanoparticle": Y. Xiao, F. Patolsky, E. Katz, J. F. Hainfeld, I. Willner, *Science*, **2003**, *299*, 1877–1881.
   This study highlights the use of enzyme–nanoparticle hybrid systems in biomolecular electronics. The study describes the electrical contacting of a redox enzyme with the electrode by means of a 1.2 nm Au nanoparticle implanted into the biocatalyst by a reconstitution process. The study follows our extensive research efforts in the electrical contacting of redox enzymes with electrodes by the surface reconstitution of apoproteins on relay cofactor units. The demonstration of a metal nanoparticle that can electrically communicate the redox sites of proteins with electrodes is a key discovery in nanobiotechnology. It guided us and other scientists to apply other metal nanoparticles, nanotubes and wires as nanoscale electronic connectors of enzymes with electrodes, and revealed the use of these modified electrodes in different bioelectronic devices such as biosensors or biofuel cells.
3. "Lighting-Up the Dynamics of Telomerization and DNA Replication by CdSe–ZnS Quantum Dots": F. Patolsky, R. Gill, Y. Weizmann, T. Mokari, U. Banin, I. Willner, *J. Am. Chem. Soc.* **2003**, *125*, 13918–13919.
   This study demonstrated the use of nucleic acid functionalized semiconductor quantum dots (QDs) as hybrid systems for optical biosensing. The study demonstrated that the QDs not only act as luminescent labels of biorecognition events, but that they can also be applied to follow the dynamics of biocatalytic transformations, such as DNA replication or telomerization, by a fluorescence resonance energy transfer (FRET) process. This study guided our research on the application of molecule- and biomolecule-functionalized QDs for optical sensing and biosensing.
4. "A Virus Spotlighted by an Autonomous DNA Machine": Y. Weizmann, M. K. Beissenhirtz, Z. Cheglakov, R. Nowarski, M. Kotler, I. Willner, *Angew. Chem.* **2006**, *118*, 7544–7548; *Angew. Chem. Int. Ed.* **2006**, *45*, 7384–7388.
   This study introduced the application of tailored nucleic acid nanostructures and DNA-based machines for the amplified, ultrasensitive detection of DNA. The study demonstrated a versatile new paradigm for the isothermal replication of a DNAzyme as a result of DNA recognition events, and it introduced an alternative amplification process to the polymerase chain reaction (PCR). This study guided us, as well as other researchers, in developing other amplifying DNA machines. The concept was adapted to detect metal ions, low-molecular-weight substrates, and proteins.
5. "Enzyme Cascades Activated on Topologically Programmed DNA Scaffolds": O. I. Wilner, Y. Weizmann, R. Gill, O. Lioubashevski, R. Freeman, I. Willner, *Nature Nanotechnol.* **2009**, *4*, 249–254.
   The study describes the self-assembly of DNA nanowires consisting of "hexagonic" building blocks, and the programmed assembly of two enzymes or a cofactor and an enzyme on the nanostructures. The novelty of the study rests on the demonstration that the programmed positioning of the components on the DNA template controls the reactivities of the resulting systems. This study has established a new research direction in nanotechnology in which self-assembled DNA nanostructures act as templates for controlling biocatalytic transformations and photocatalytic processes, and provide organized matrices for the controlled growth of metallic nanowires. These systems hold great promise in biotechnology, biosensor design, and nanoelectronics.

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