



Professor Chad Mirkin
George B. Rathmann Professor of Chemistry,
Medicine, Materials Science & Engineering, Biomedical
Engineering, Chemical & Biological Engineering
Northwestern University
USA



**Northwestern
University**

Michael H. Schill
President

January 11, 2024

Dear Selection Committee:

We enthusiastically nominate Professor Chad A. Mirkin of Northwestern University for the Albert Einstein World Award of Science. Indeed, Mirkin is responsible for many of the foundational tools and techniques that define the modern age of nanotechnology. This award is given to those individuals who “open a door” by profoundly changing the way we think about the world around us and develop new technologies that benefit humankind. *Mirkin’s invention and development of spherical nucleic acids (SNAs), colloidal crystal engineering with DNA, cantilever-free, scanning probe-enabled synthesis and materials discovery methodologies, high-area rapid printing (HARP), and the commercial products and process that are based upon them,* combined with his translational accomplishments, make him an ideal candidate.

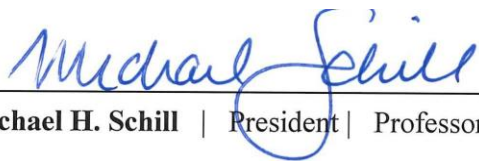
Case in point, SNA nanostructures, which define a new form of one of the most important molecules ever synthesized by chemists (DNA), are the cornerstones of the Verigene® medical diagnostic system and SmartFlares™. The FDA-cleared Verigene® medical diagnostic system ([Luminex/DiaSorin - Verigene](#)) is utilized in over half of the world’s top hospitals. Through millions of tests run each year, the Verigene is permitting diseases to be detected earlier (e.g., sepsis, respiratory diseases like flu and COVID-19, and gastrointestinal ailments like *C. difficile*) and new genetic markers for Alzheimer’s disease, HIV, cardiac disease, and cancers to be identified. SmartFlares™ were commercialized by AuraSense, a company founded by Mirkin, with Merck Millipore ([Merck-Millipore SmartFlares](#)). Over 1,600 versions of SmartFlares™ have been used globally in the life sciences as intracellular probes for tracking and differentiating cells based upon genetic content. SNA nanostructures also form the basis for a new therapeutic pipeline for gene regulation and cancer immunotherapy, including six drugs in human clinical trials (e.g., SNAP Therapeutics and Northwestern’s Feinberg School of Medicine).

Furthermore, Mirkin invented and is the chief developer of scanning probe-based molecular printing and materials discovery tools that were commercialized through TERA-print ([www.tera-print.com/](#)) and Matteredra (formerly Stoicheia, [www.stoicheia.us/](#)). These tools are now used by hundreds of researchers, spanning three different continents. Finally, Mirkin also is the inventor and developer of HARP, the highest throughput stereolithography (SLA) 3D printing technology in the world, which allows one to print large objects at unparalleled speeds (17” per hour) from industrial-grade polymer precursors. Used heavily by DuPont and Wilson Sports, Azul 3D’s (a Mirkin-founded company) LAKE 3D printer has been used to fabricate critical components for microelectronics, sportswear and equipment, and face shields to the immense benefit of healthcare workers battling COVID-19 ([WGN tv news story](#)).

From our perspective, these accomplishments strongly distinguish Mirkin from what must be a large pool of very talented nominees.

We urge you to carefully consider and select Mirkin as this year's winner of the Albert Einstein World Award of Science.

Yours sincerely,

A handwritten signature in blue ink, reading "Michael Schill". The signature is fluid and cursive, with the first name and last name clearly distinguishable.

Michael H. Schill | President | Professor of Law and Professor of Finance & Real Estate

A handwritten signature in blue ink, reading "Fraser Stoddart". The signature is fluid and cursive, with the first name and last name clearly distinguishable.

Sir Fraser Stoddart | 2016 Nobel Laureate in Chemistry | Board of Trustees Professor of Chemistry



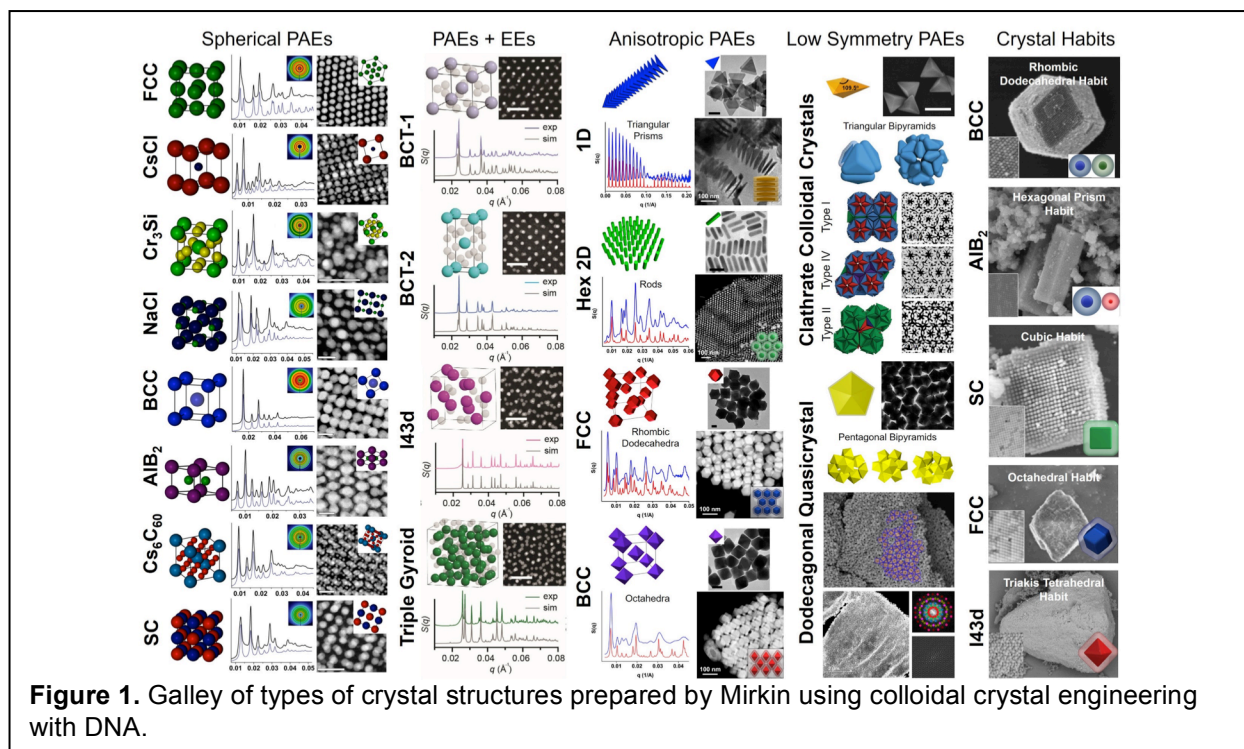
December 12, 2022

Dear Selection Committee:

I enthusiastically support the nomination of Professor Chad Mirkin for the Albert Einstein World Award of Science. The reactions, techniques, and tools he has developed have changed the way we think about chemical systems, synthesize and study matter, and positively impacted many. Mirkin's spherical nucleic acid work is most notable.

I have known Chad for decades – we came up through the ranks together. He first introduced spherical forms of nucleic acids – or SNAs – in that *Nature* article (over 7,800 citations according to Google Scholar), and it is amazing to see how far this work has progressed since then. Chad has utilized SNAs, structures composed of nanoparticle cores with highly densely functionalized, highly oriented DNA shells, and their analogous anisotropic equivalents to develop a new field of materials chemistry for designing and synthesizing colloidal crystals. His colloidal chemistry offers versatility in making new structures. *The number of variations made possible with different types of oligonucleotides provides a chemical richness that is important.* I elaborate on this work below.

Atoms are nature's building blocks, but they only couple with certain elemental partners in particular symmetries dictated by fundamental chemical rules, and thus the number of possible higher-order structures one can make is limited. With atoms, composition is inexorably tied to structure, and the inability to independently tune atomic properties to create new materials is a significant roadblock. By introducing the concept of nanoparticles as similar to "atoms" and nucleic acids as similar to "programmable bonds" (*Nature* **1996**, 382, 607; *Angew. Chem.* **2013**, 52, 5688; *Science* **2015**, 347, 1260901; *Nature Rev. Mater.* **2019**, 4, 201), Chad has shown how one can decouple the composition and



properties of building blocks from how they bond. PAE properties can be regulated by changing the core composition, shape, and size and the nucleic acid bonding strength, length, or type. For example, Chad has shown that directional bonding can be achieved with core shape or DNA placement with PAEs. Furthermore, Chad has introduced a new “table of elements” of nanoparticle building blocks that is not “periodic” but near-infinite, allowing greater versatility in design.

Chad introduced crystal engineering design rules for using the nucleic acid component of PAEs to program colloidal crystallization (*Nature* **2008**, 451, 553; *Nature Mater.* **2010**, 9, 913; *Science* **2011**, 334, 204; *Nature Mater.* **2013**, 12, 741; *Science* **2013**, 341, 1222; *Science* **2016**, 351, 579; *Science* **2017**, 355, 931; *Nature Mater.* **2022**, 21, 580). These rules, which some have likened to Pauling’s Rules, allow one to deliberately control crystallographic symmetry, particle composition, lattice parameters, and even crystal habit. Chad has predictably and reliably synthesized PAEs of >70 different crystal symmetries to-date - common FCC and BCC forms as well as exotic ones with no known mineral equivalent (Figure 1). He has delineated how to tune the lattice parameters of these structures over an order of magnitude with nanometer-level precision, and he has made lattices with one, two, and three components and some that can “shape-shift” between phases. Chad has shown how nanoparticle superlattices could be prepared with reconfigurable surface ligands that respond to chemical cues that allow them to crystallize along different pathways (a true analogy to pluripotent stem cells and a significant step forward in synthesizing dynamic, adaptive matter). He also has employed many core materials, and each SNA, regardless of core, crystallizes according to the same rules, enabling one to utilize each entity interchangeably to construct elaborate multi-component structures. The protein-cored SNA in particular shows how uncontrollable protein-protein interactions can be swapped out with well-defined and programmable DNA-DNA interactions to allow for deliberate protein crystal growth (*JACS* **2017**, 139, 1754; *Acc. Chem. Res.* **2019**, 52, 1939), and dendrimer chemistry is affording molecular-level control of the building blocks in these lattice systems (*JACS* **2021**, 143, 1717).

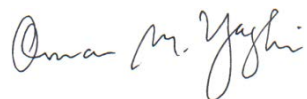
Chad demonstrated that thermal annealing processes can be used to form single crystals of PAEs in the form of the theoretically predicted Wulff polyhedra (*Nature* **2014**, 505, 73). He has transferred these lattices to the solid state (*Adv. Mater.* **2012**, 24, 5181) and grown them epitaxially on substrates (*Angew. Chem.* **2013**, 52, 6624; *Nano Lett.* **2013**, 13, 6084; *ACS Nano* **2017**, 11, 180). The ability to place nanoparticles of any composition and shape at any location in a well-defined crystalline lattice with nanometer-scale precision on demand has far-reaching implications in chemistry, and Chad is already figuring out how to apply his lattices spanning metamaterials to energy (*JACS* **2015**, 137, 1658; *PNAS* **2015**, 112, 977; *PNAS* **2018**, 115, 7242; *Science* **2018**, 359, 669; *PNAS* **2020**, 117, 21052; *Adv. Mater.* **2020**, 32, 2005316).

Just recently, Chad’s work was featured in back-to-back issues in *Nature*. In one paper, Chad identified and explored a novel type of shape memory in colloidal crystals so large that such mechanical properties could be observed optically (*Nature* **2022**, 610, 674). Essentially, these crystals return to their original structures after deformations that would leave conventional crystals irreversibly damaged owing to the properties of the DNA linkages within the crystal. These structural/mechanical changes are accompanied by reversible optical changes that make these nanosystems interesting for exploration in sensing, robotic, and energy applications. In the other paper, Chad delineated two new design rules that constitute a universal approach for synthesizing metallic open-channel superlattices with pores in the 10 to 1,000-nm range using DNA-modified hollow anisotropic colloidal nanoparticles (*Nature* **2022**, doi: 10.1038/s41586-022-05291-y). These materials are useful for a variety of host-guest reactions. The high-profile nature of these articles is indicative that Chad’s work in this area, despite enormous success already, is only continuing to accelerate.

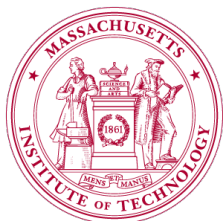
The impact of Chad’s work with oligonucleotide-nanoparticle conjugates in developing new

chemistry to synthesize colloidal crystals has paved the way to understanding some of the most complex issues in crystal engineering and programmable materials synthesis and spurred the development of new crystallography techniques for the analysis of novel nanoscale systems. Colloidal crystal engineering with DNA includes thousands of researchers. Furthermore, Chad is using such advances to reframe key topics in general chemistry. In fact, concepts from his research are so foundational that he is working to integrate them into a general chemistry textbook. Moreover, he laid out his pedagogy for integrating nanochemistry, and more specifically the analogies between atomic bonding and the DNA bond into general chemistry courses in an article in *J. Chem. Educ.* (**2021**, 98, 3090). He broached the subject for a more advanced audience in *Adv. Mater.* (**2022**, 34, 2107875). He has developed an entire new class of crystalline matter, elucidated its chemical and physical properties, and applied it to open new fields and benefit society. He is a most worthy candidate, and I strongly encourage the committee to consider Chad for the Albert Einstein World Award of Science for his SNA work, as well as other immense contributions to nanochemistry, and for his service-oriented, entrepreneurial, and educational contributions worldwide.

Best regards,

A handwritten signature in black ink, reading "Omar M. Yaghi". The signature is fluid and cursive, with the first name "Omar" and last name "Yaghi" being more prominent than the middle initial "M".

Omar M. Yaghi



**MASSACHUSETTS INSTITUTE OF TECHNOLOGY
DEPARTMENT OF CHEMISTRY
CAMBRIDGE, MASSACHUSETTS 02139-4307**

TIMOTHY M. SWAGER
JOHN D. MACARTHUR PROFESSOR

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December 6, 2022

Dear Selection Committee:

I write in strong support of the nomination of Professor Chad Mirkin for the Albert Einstein World Award of Science. Chad is a leading innovator in the field of nanochemistry. Indeed, his accomplishments at the intersection of materials chemistry, inorganic chemistry, and colloid and surface chemistry, especially those with applications to health-related technologies, are simply unparalleled. Relevant to this award, Chad has made many seminal contributions surrounding the synthesis and development of gold nanoparticles functionalized with biomolecules, specifically nucleic acids like DNA and RNA, that have not only opened new domains in nanoscience and technology, but have made marked impacts in society through their application in transformational life science and medical technologies.

To sum it up, Chad Mirkin can be given the lion's share of the credit for the modern exploitation of nanoparticles in biodetection, sensing, and gene regulation and immunotherapy technologies. This research began in 1996 with Chad demonstrating that DNA can control the plasmonic interactions between gold nanoparticles. This interaction is triggered by DNA hybridization and is accompanied by a red-to-blue color change. The key to this technology is that Chad realized how he could use DNA binding to surface-bound complements to control inter-particle distance. There are other interesting features surrounding this observation. Indeed, Chad also demonstrated that melting curves are much more cooperative (sharper) when the DNA is associated with nanoparticles (versus with the same sequence free in solution; an entropic effect). This feature can give higher fidelity in the recognition of specific sequences of DNA in the presence of single-base mismatches. These fundamental scientific breakthroughs, which highlight the unique chemistry of the system, led to Chad's founding of Nanosphere, which commercialized these methods as they pertain to medical diagnostics, including the detection of proteins. Nanosphere was acquired by Luminex, and the technology Chad invented that underlies the Verigene System (in over half the world's top hospitals) is a major revenue stream for Luminex/DiaSorin. Simple color change types of technologies like this one have great potential in health care. The chemical concepts elucidated by Chad gave rise to systems that are sufficiently easy to use and inexpensive such that they can be performed at the point-of-care, in the home, or at small clinics. It is clear that this type of technology is needed to combat the high cost of health care and the overheads associated with large hospitals. This commercial success has been key in ushering in a new era of medical diagnostics.

The bounds of Chad's innovations seem to have no limits. In recent years, he has shown that the oligonucleotide nanoparticle conjugates, which form the basis for diagnostic probes, can also be used to create a powerful new class of genetic medicines. Specifically, he has shown that a new form of DNA templated on spherical nanoparticles, which he describes as Spherical Nucleic Acids, or SNAs, are exceedingly useful as gene regulation therapies and immunotherapeutics for the effective treatment of a number of diseases. The ability of SNAs to deliver an effective genetic payload to cells, and even topically through the skin, is simply transformational. SNAs have high efficacy relative to all other forms of DNA and RNA. By using concepts from chemistry and

nanoscience to organize nucleic acids into spherical forms, Chad has shown that such structures can engage natural cellular machinery ubiquitous to all cells (scavenger receptors) to efficiently and actively enter cells and bind their targets. Hence, you get greater effects with less material. He beautifully mapped out the fundamental pathways involved in these processes and utilized that understanding to create a pipeline of drugs that are now in the clinic for GBM (a lethal brain cancer), psoriasis, and many forms of cancer (via immunotherapy and SNA stimulation of TLR9 receptors with checkpoint inhibitors). This technology is being commercialized and, by all accounts, SNAs are displaying results that will enable entirely new possibilities for personalized and precision medicine. *Their impact on human health could be at the level of innovations such as the development of orally effective antibiotics. History is in the making here, and the breadth of Chad's impact from nanoscience to surface chemistry to medicine is truly amazing.*

In a completely separate, but no less significant area, Chad pioneered a technique known as dip-pen nanolithography (DPN). In this method, a small tip is brought in close proximity to a surface and, when wet with a chemical, the tip can essentially deposit a small nanometer scale chemical pattern. In this way, it resembles an old-style ink pen from which a drop of ink is slowly deposited upon a page. The power of this method is that it allows a person to draw essentially any two-dimensional feature on a desired surface. Chad founded a company named NanoInk that developed commercial versions of such systems, including highly parallel methods wherein many tips can simultaneously produce multiple copies of a desired object. More recently, he founded TERA-print to advance related cantilever-free systems that he invented, like polymer pen lithography (PPL) and beam pen lithography (BPL), and Mattera (formerly Stoicheia) that employs such systems to integrate AI with big data in the context of massive nanoparticle libraries consisting of millions of unique particles.

PPL is also notable for its implications in biology and the life sciences; PPL is ideal for the direct-writing of soft materials, such as proteins. The elastomeric tips in PPL make force- and time-dependent control over feature parameters possible. In this way, the patterning process can be manipulated to prepare nanocombinatorial arrays of chemically and biologically diverse features on a single substrate. Chad has demonstrated how such arrays could be used to probe mesenchymal stem cell differentiation and even drive these cells toward particular fates. Mirkin also coupled PPL with self-assembled monolayer laser desorption/ionization (SAMDI) mass spectrometry to synthesize substrates comprised of peptides and extracellular matrix (ECM) proteins optimal for both cell culture and subsequent enzymatic analysis – an accomplishment with important implications in drug screening and development. These methods have been very important to those in the research community, who wish to fabricate and organize chemical and biological structures on a nanometer length scale, and they are ushering in the new area of nanocombinatorics. Importantly, DPN and the related cantilever-free methodologies do not require the types of instrumentation or clean rooms and associated capital costs that traditionally have limited nanofabrication capabilities in the past. The ramifications of these methods continue to grow in the medical community, and they are already widely practiced by researchers all over the world. It is clear that this technology will enable the development of many new chemistry-based nanotechnologies that will benefit humankind.

As I have indicated, Chad Mirkin is one of the highest impact scientists and inventors of his generation. In addition to an unparalleled publication record in chemistry and related fields, he has pushed paradigm-shifting technologies into the marketplace. Such impact is critical to the future of basic science and should be admired. Chad is one of the most cited chemists in the world. His service to the chemistry community has been outstanding as a *JACS* Associate Editor and leader on a number of US governmental committees including the President's Council of Advisors on Science

and Technology (PCAST; 8 years with the Obama Administration). He has trained over 300 Ph.D.-level scientists and postdocs in academia and industry (over 125 of the most successful professors working in science, engineering, and medicine today; we have one at MIT and there is another at Harvard). He must be recognized as a leading visionary of our time in recognizing how chemistry and nanoscience can be applied and make a difference in the real world. In summary, Chad Mirkin's accomplishments are most deserving of the Albert Einstein World Award of Science, and I can think of no better candidate.

Sincerely,

A handwritten signature in black ink, appearing to read "Timothy M. Swager". The signature is fluid and cursive, with a long horizontal stroke extending to the right.

Timothy M. Swager

CHAD MIRKIN is most deserving of the Albert Einstein World Award *for developing many of the foundational tools and techniques that have defined the modern age of nanotechnology, including the invention and development of spherical nucleic acids (SNAs), the concepts underlying colloidal crystal engineering with DNA, cantilever-free scanning probe-enabled synthesis and materials discovery methodologies, and high-area rapid printing (HARP), and the commercial products and process that are based upon them.* He has perhaps done more to develop nanoscience, particularly in the realms of chemistry, materials science, and biology, than any single researcher in the world. His discoveries have established new scientific fields and are significantly impacting humanity.

I. Colloidal Crystal Engineering with DNA: Mirkin utilized SNAs and their analogous anisotropic equivalents to develop an entire new field of chemistry and materials science, focused on using such structures as “programmable atom equivalents” (PAEs) for synthesizing colloidal crystals. In 1996, he developed the chemistry for modifying nanoparticles with dense layers of highly oriented oligonucleotides to create structures where the directionality of the DNA is dictated by the nanoparticle template. Since then, he has explored extensively the concept and power of the DNA “bond” (i.e., double-strand formation) in programming the crystallization of all kinds of building blocks into superlattice structures with nanometer-level precision over lattice parameters and even crystal habits. ***Mirkin showed the world how one can create “atoms” from particles with bonding properties independent of “atomic” identity.*** This is an enabling observation that allowed him to create design rules for assembly that are akin to Pauling’s rules – but substantially more predictive and powerful in that they work for a wide range of particle compositions. ***This work is taking materials-by-design to entirely new levels.*** Mirkin has prepared new classes of metamaterials and catalysts and demonstrated how DNA bonds can be used to synthesize stimuli and environmentally responsive architectures, including dynamic lenses, lasing materials, catalysts, wavelength-dependent reflectors, and materials with negative refractive indices.

II. Spherical Nucleic Acids in Biomedicine: Over the past two decades, Mirkin has shown that SNAs, in their cored and hollow (core-less) forms, possess chemical and physical properties that are inherently different from those of linear and two-dimensional forms of DNA and RNA with the same sequence. These characteristics make them exceedingly useful in biology and medicine. SNAs exhibit a synergistic combination of properties resulting from the central core and the nucleic acid shell, including their ability to cooperatively hybridize with complementary nucleic acids and form stronger duplexes than the same sequence of linear DNA. SNAs also can be used to transfect cell membranes efficiently without the need for co-carriers, and they operate in both RNAi and antisense gene-regulation pathways, a paradigm shift in the field. The lore prior to Mirkin’s discovery of SNAs was that nucleic acids, in the absence of positively charged co-carriers, could not enter cells with any efficiency. Not so with SNAs, which, unlike their linear counterparts, can complex scavenger proteins (Class A) that facilitate endocytosis. Mirkin worked out the mechanism for SNA uptake and processing and has shown that these nanostructures resist enzymatic degradation and do not trigger an adverse immune response, i.e., they are non-toxic.

Biodiagnostics. SNA technology has widely popularized the notion of toggling highly specific biomolecular interactions in “sandwich” assay-type formats, and Mirkin has developed them as probes for the highest sensitivity protein and non-PCR-based nucleic acid-based assays. As such, they enabled some of the first commercial point-of-care medical diagnostic systems (the FDA-cleared Verigene®, Mirkin’s company Nanosphere and now Luminex/DiaSorin) and the only materials that can enter live cells and be used to identify and quantify genetic content at the single-cell level (SmartFlares™, Mirkin’s company AuraSense and Merck Millipore).

Drug Design and Delivery. SNAs also constitute a powerful new single-entity gene regulation and advanced immunotherapeutic platform for glioblastoma multiforme (GBM, brain cancer) and a broad range of other cancers. SNAs represent a revolutionary way to design and make personalized, precision medicines because they harness the power of digital drug design, wherein a new drug can be made by formulating a new oligonucleotide sequence on the SNA surface. This strategy permits the rapid identification of target molecules and low-cost, accelerated development (via Northwestern and Mirkin’s companies, including SNAP Therapeutics). Mirkin utilized SNAs to redefine the field of immunotherapeutics by showing how

adjuvants and antigens are presented on SNA immunotherapeutic agents (i.e., the chemical structure of the conjugate), effectively transitioning these drugs from being mildly effective to being curative. Mirkin has shown that SNAs employing prostate-antigen-specific peptide sequences, which have previously failed in clinical trials, enhance the immune response. Thus, improved and specific immune responses can be achieved based on vaccine architecture. In the context of COVID-19, Mirkin invented and developed the first SNA-based *antiviral* vaccine.

III. Cantilever-free, Scanning Probe Tip-Based Synthesis, and Materials Discovery: Mirkin was first to introduce dip-pen nanolithography (DPN), a scanning probe lithography-based technique wherein atomic force microscope tips are used to create patterns directly on a range of substances with a variety of chemical and biological inks in 1999. Since then, he has gone on to develop a bevy of other related methodologies that have enhanced this platform in terms of its chemical and materials patterning capabilities, resolution, throughput, and large-scale printing abilities, while lowering its cost and increasing its simplicity. Among these methods, polymer pen lithography (PPL) uses a soft elastomeric tip array to deliver molecular inks to a surface in a direct-write manner. Mirkin also introduced scanning probe block copolymer lithography (SPBCL), which employs polymeric inks in PPL. And, in 2016, Mirkin utilized SPBCL to synthesize MegaLibraries, which are high-density arrays consisting of billions of nanoparticles that are deliberately made to systematically vary in size and composition (i.e., a gradient of structures). These tools can be used to rapidly design, screen, and identify new nanoarchitectures with almost any desired chemical or physical property. ***To put this in perspective, Mirkin can synthesize and study more new inorganic materials in one experiment than have been made by scientists cumulatively to date using conventional serial syntheses.*** Exceedingly important from an applied standpoint, Mirkin's techniques allow one to design new catalysts for diverse chemical transformations and routes to structures with unusual phase behavior and magnetic or plasmonic characteristics. Mirkin has employed MegaLibraries to identify novel catalysts for transforming low-value feedstocks into high-value materials, including a previously unknown three-element nanostructure seven times more efficient than the state-of-the-art Pt/C catalyst used for the hydrogen-evolution reaction (HER) to produce the alternative fuel hydrogen (H₂) and for facilitating olefin hydrogenations, CO₂ reduction, and carbon nanotube growth, with applications in pharmaceuticals, energy, and agriculture. Mirkin's understanding of the meniscus phenomenon (formed via the capillary effect) led to its use as a solvent to facilitate the direct transport of chemically reactive entities from a tip to a surface. This approach forms the basis for all commercial scanning probe molecular printing tools, including those commercialized through companies he founded (TERA-print) and more recently Mattera (formerly Stoicheia). TERA-print's instruments have been installed in seven countries spanning three continents.

IV. High-Area Rapid Printing (HARP): Mirkin has turned his attention to the advanced manufacturing industry, and his advances are making major inroads. He founded a company, Azul 3D, that is developing high-throughput 3D printing technology, namely High-Area Rapid Printing (HARP), that takes ideas from prototyping to manufacturing in a streamlined, low-cost manner. HARP allows one to print large objects at unparalleled speeds (17" per hour) from a wide range of consumer and industrial-grade plastics to meet any demand, going directly from the printer to the shelf. Innovations in this process combine advanced interfacial surface chemistry and heat-management systems.

It should be noted that the economic impact of Mirkin's technologies is substantial and rapidly growing. Mirkin founded his first company, Nanosphere, based on SNAs in 1999. Since then, his companies (11 of them) have employed hundreds of people and have grossed revenues of over 100 million US\$/year (a conservative estimate).

Mirkin has used fundamental scientific discoveries to fuel extraordinary technological development spanning medicine to materials engineering, oftentimes seeing advances through from inception to translation (a rarity). His work is well-vetted through his receipt of over 240 national and international awards, including top awards from multiple countries in Europe. Internationally, his name is synonymous with nanoscience. We urge you to recognize Mirkin with the World Award of Science to acknowledge the breadth and depth of fields of science and technology that have been positively impacted by his work.

CHAD A. MIRKIN, PH.D.

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Education

- 1991 NSF Postdoctoral Fellow in Chemistry, Massachusetts Institute of Technology, Cambridge, MA
- 1989 Ph.D. in Inorganic & Organic Chemistry, The Pennsylvania State University, State College, PA
- 1986 B.S. in Chemistry (Phi Beta Kappa), Dickinson College, Carlisle, PA

Professional Experience

- 2008-present Director, International Institute for Nanotechnology; George B. Rathmann Professor of Chemistry, Medicine, Materials Science & Engineering, Biomedical Engineering, Chemical & Biological Engineering, Northwestern University
- 2004-2008 Director, International Institute for Nanotechnology; George B. Rathmann Professor of Chemistry, Medicine, and Materials Science & Engineering, Northwestern University
- 2000-2004 Director, Center for Nanofabrication and Molecular Self-Assembly and George B. Rathmann Professor of Chemistry, Northwestern University
- 1997-2000 Charles E. and Emma H. Morrison Professor of Chemistry, Northwestern University
- 1995-1997 Associate Professor, Department of Chemistry, Northwestern University
- 1991-1995 Assistant Professor, Department of Chemistry, Northwestern University

Awards and Honors (selected, over 250 national and international total; last 20 years)

- 2023 King Faisal Award in Science
- 2022 *Acta Biomaterialia* Gold Medal; MRS Medal; Faraday Medal (IET); STEM Leadership Award for Outstanding Entrepreneurial Innovation (CME); John P. McGovern Science and Society Award (Sigma Xi); International Precious Metals Institute (IPMI) Jun-ichiro Tanaka Distinguished Achievement Award
- 2021 Royal Society of Chemistry (RSC) de Gennes Prize; G. M. Kosolapoff Award (Auburn University/Auburn ACS Local Section)
- 2020 ACS Division of Colloid and Surface Science Award for Outstanding Achievement in Nanoscience; AAAS Philip Hauge Abelson Award
- 2019 Kabiller Prize in Nanoscience and Nanomedicine; SCI Perkin Medal; Netherlands Award for Supramolecular Chemistry; Yao Yuan Innovation Award; Harry and Carol Mosher Award (Silicon Valley ACS Local Section)
- 2018 Ralph N. Adams Award in Bioanalytical Chemistry; *Nano Research* Award; Harrison Howe Award (Rochester ACS Local Section); Remsen Award (Johns Hopkins/Maryland Section of the ACS); Theodore William Richards Medal (Northeastern ACS Local Section)
- 2017 Nichols Medal (New York ACS); Dickson Prize in Science; Wilhelm Exner Medal; ACS Fellow; Honorary Professor, Jiangnan University; Crain's Chicago Business Tech 50 2017; "10 Top 10s" Analytical Scientist Power List; Nano Today Award
- 2016 American Institute of Chemists Gold Medal; Thomson Reuters Highly Cited Researcher; Honorary Professor, Shanghai Institute of Applied Physics, Chinese Academy of Sciences; RUSNANOPRIZE; American Institute of Chemists Life Fellow; International Precious Metals Institute 2016 Student Advisor Award; Dan David Prize (Israel)
- 2015 RSC Centenary Prize; American Institute for Medical and Biological Engineering Fellow; Thomson Reuters Highly Cited Researcher; NAS Raymond and Beverly Sackler Prize in Convergence Research
- 2014 Friends of the National Library of Medicine Distinguished Medical Science Award; Honorary Degree, Universidade Federal do Rio Grande do Sul; Vannevar Bush Faculty Fellowship; Thomson Reuters Highly Cited Researcher (2002-2012); ACS *Nano* Lectureship Award for the Americas; The Electrochemical Society's Vittorio deNora Award; Fellow RSC; Honorary Fellow of the Chinese Chemical Society
- 2013 Honorary Professor of ShanghaiTech University; National Academy of Inventors Fellow; Thomas Reuters Citation Laureate (Nobel Watch); Walston Chubb Award for Innovation; MRS Fellow; Honorary Member

- of the Materials Research Society of India (MRSI); Linus Pauling Award (Puget Sound, Oregon, Portland ACS); RSC's "Chemistry World" Entrepreneur of the Year Award
- 2012 International Material Science Award, International Centre for Materials Science, Bangalore, India; Honorary Professor, Hunan University, China; Lee Kuan Yew Distinguished Visitor to Singapore; Honorary Degree, Nanyang Technological University, Singapore; ACS Award for Creative Invention
- 2011 Member of the American Academy of Arts and Sciences; Van't Hoff Prize
- 2010 Member of the National Academy of Medicine, Member of the National Academy of Sciences; Herman S. Bloch Award for Scientific Excellence in Industry, University of Chicago; Einstein Professorship of the Chinese Academy of Sciences (CAS); Ohio State University Edward Mack Jr. Memorial Award
- 2009 \$500,000 Lemelson-MIT Prize; Member, President's Council of Science & Technology (PCAST, Obama Administration); Member of the National Academy of Engineering; Havinga Medal, Leiden University, The Netherlands; Thomson Reuters Most Cited Chemist in the World (#1); Gustavus John Esselen Award; Pittsburgh Analytical Chemistry Award
- 2008 Biomedical Engineering Society's Distinguished Achievement Award; Vannevar Bush Faculty Fellowship; ACS Inorganic Nanoscience Award
- 2007 iCON Innovator of the Year Award; Elected Alumni Fellow, Pennsylvania State University
- 2006 Phi Beta Kappa, Dickinson College
- 2005 Board of Trustees, Dickinson College
- 2004 NIH Director's Pioneer Award; Collegiate Inventors Award, National Inventors Hall of Fame; Pennsylvania State University Outstanding Science Alumni Award; Dickinson College Honorary Degree
- 2003 Collegiate Inventors Award, National Inventors Hall of Fame; Raymond and Beverly Sackler Prize in the Physical Sciences, Tel Aviv University, Israel; Dickinson College Metzger-Conway Fellowship Award; ACS Nobel Laureate Signature Award for Graduate Education in Chemistry; The Forbes/Wolfe Nanotech Report, "Nanotechnology's Top 10 Power Brokers"
- 2002 Feynman Prize in Nanotechnology; Esquire Magazine's "Best & Brightest in the Nation"

Center Leadership (selected)

- Director, Center for NanoCombinatorics (2021-present)
- Director, Convergence Science & Medicine Institute (CSMI) (2019-present)
- Director, Ronald and JoAnne Willens Center for Nano Oncology (2015-present)
- Director, Air Force Center of Excellence for Advanced Bioprogrammable Nanomaterials (C-ABN; 2015-2021)
- Director, NTU-Northwestern Institute for Nanomedicine (2014-2019)
- Director, Northwestern Center of Cancer Nanotechnology Excellence (2005-2021)
- Director, NSF Nanoscale Science and Engineering Center (2001-2012)

Global Outreach (selected)

- Scientific Advisory Board, Digital Medicine & Artificial Intelligence Translational Research Program (WISDM), Yong Loo Lin School of Medicine, National University of Singapore (2022-present)
- National University of Singapore Exxon Mobil Visiting Chair Professor, Department of Chemical and Biomolecular Engineering (2018-2019)
- Scientific Advisory Board, Institute for Basic Science Center for NanoMedicine, Yonsei University (2017-present)
- Advisory Co-Director, Institute of Chemical Biology and Nanomedicine (ICBN), Hunan University, China (2013-2018)
- Chairman of the Advisory Committee, Nanyang Institute of Technology in Health and Medicine, Nanyang Technological University, Singapore (2013-2018)
- Advisor to the President of Nanyang Technological University (2009-2017)

National Service (selected)

- Member of the President's Council of Advisors on Science and Technology (PCAST, Obama Administration; 2008-2016)

- Technology Advisory Group Member of the President's Council of Advisors on Science and Technology (PCAST, Bush Administration)
- Nanotechnology Technical Advisory Group (nTAG)
- Science and Technology Experts Group (ISTEG), administered by the National Academies of Sciences, Engineering, and Medicine (2017-present)
- Delegate at Asia-Pacific Economic Cooperation (APEC) 2011 Summit (Honolulu, HI), with 21 world leaders including President Barack Obama, Secretary of State Hillary Rodham Clinton and representatives from Fortune 500 companies.
- Speaker, APEC 2011 Summit, Honolulu, HI; "Game Changing Technology Redefining the Region" (2011) with President of Chile, Sebastian Piñera Echenique
- Member of the Temporary Nominating Group (TNG) of the National Academy of Sciences (NAS), responsible for ensuring equal representation in the NAS by facilitating the election of eight diverse candidates (2011-2017).
- Testimony before the U.S. Senate Committee on Commerce, Science, and Transportation, July 14, 2011
- Member, ACS Presidential Commission on Graduate Education in the Chemical Sciences, which produced the report, "Advancing Graduate Education in the Chemical Sciences"
- Co-chaired the world study on nanotechnology research directions for societal needs resulting in: *Nanotechnology Research Directions for Societal Needs in 2020: Retrospective and Outlook*, Boston and Berlin: Springer **2010**. Roco, M. C.; Mirkin, C. A.; Hersam, M. C., editors.
- Contributed a chapter in *Nanotechnology Research Directions for Societal Needs in 2020: Retrospective and Outlook*, Roco, M. C.; Mirkin, C. A.; Hersam, M. C., editors, Boston and Berlin: Springer **2010**. Mirkin, C. A.; Nel, A.; and Thaxton, C. S. "Applications: Nanobiosystems, Medicine, and Health" pgs. 209-260.
- Contributed a chapter in *Nanotechnology Research Directions for Societal Needs in 2020: Retrospective and Outlook*, Roco, M. C.; Mirkin, C. A.; Hersam, M. C., editors, Boston and Berlin: Springer **2010**. Mirkin, C. A.; Tuominen, M. "Synthesis, Processing, and Manufacturing of Components, Devices, and Systems," pgs. 61-98.
- Co-Chair, PCAST report titled, "Engage to Excel" focusing on teaching and engagement issues involving students who are in their first two years of undergraduate study at R-1, 2 & 4-year institutions, and community colleges.

Editorial Activities (selected)

- Associate Editor, *Journal of the American Chemical Society* (2012-2021)
- Member Editor, *Proceedings of the National Academy of Sciences*
- Editorial Board Member, *Proceedings of the National Academy of Sciences* (2018-present)
- Founding Editor, *Small*
- Member of the Editorial Advisory Boards of over 30 scholarly journals: (e.g., *Nano Letters*, *ACS Nano*, *Journal of the American Chemical Society*, *Angewandte Chemie International Edition*, *Advanced Materials*)

Conference Organization and Leadership (selected)

- International Organizing Committee, PACIFICHEM 2020 and PACIFICHEM 2025 (2016-present)
- Gordon Research Conferences (GRC) Conference Evaluation Committee (CEC) (2016-2021)

Publications: over 850 (over 80 in *Science* and *Nature*)

Patents and Patent Applications: over 1,200 filed worldwide (over 400 issued)

Distinguished Lectureships and Invited Seminars: over 880

Companies Founded: Nanosphere, Inc. (Nasdaq: NSPH); NanoInk, Inc.; AuraSense, LLC; AuraSense Therapeutics, LLC; TERA-print, LLC; Azul 3D; Stoicheia; Holden Pharma

Students Taught: over 300 graduate students and postdoctoral fellows and thousands of undergraduate students (over 125 alumni hold faculty positions at research institutions worldwide)

Professor Chad A. Mirkin

10 Significant Papers

1. Mirkin, C. A.; Letsinger, R. L.; Mucic, R. C.; Storhoff, J. J. "A DNA-based Method for Rationally Assembling Nanoparticles Into Macroscopic Materials," *Nature*, **1996**, 382, 607–609.
2. Piner, R. D.; Xu, F.; Zhu, J.; Hong, S.; Mirkin, C. A. "Dip Pen Nanolithography," *Science*, **1999**, 283, 661–663.
3. Taton, T. A.; Mirkin, C. A.; Letsinger, R. L. "Scanometric DNA Array Detection with Nanoparticle Probes," *Science*, **2000**, 289, 1757–1760.
4. Rosi, N. L.; Giljohann, D. A.; Thaxton, C. S.; Lytton-Jean, A. K. R.; Han, M. S.; Mirkin, C. A. "Oligonucleotide-Modified Gold Nanoparticles for Intracellular Gene Regulation," *Science*, **2006**, 312, 1027–1030.
5. Huo, F. W.; Zheng, Z. J.; Zheng, G. F.; Giam, L. R.; Zhang, H.; Mirkin, C. A. "Polymer Pen Lithography," *Science*, **2008**, 321, 1658–1660.
6. Macfarlane, R. J.; Lee, B.; Jones, M. R.; Harris, N.; Schatz, G. C.; Mirkin, C. A. "Nanoparticle Superlattice Engineering with DNA," *Science*, **2011**, 334, 204–208.
7. Chen, P.-C.; Liu, X.; Hedrick, J. L.; Xie, Z.; Wang, Shunzhi; Lin, Q.-Y.; Hersam, M. C.; Dravid, V. P.; Mirkin, C. A. "Polyelemental nanoparticle libraries," *Science*, **2016**, 352, 1565–1569, doi: 10.1126/science.aaf8402.
8. Wang, Shuya; Qin, L.; Yamankurt, G.; Skakuj, K.; Huang, Z.; Chen, P.-C.; Dominquez, D.; Lee, A.; Zhang, B.; Mirkin, C. A. "Rational Vaccinology with Spherical Nucleic Acids," *Proc. Natl. Acad. Sci. USA*, **2019**, 116, 10473–10481.
9. Walker, D. A.; Hedrick, J. L.; Mirkin, C. A. "Rapid, large-volume, thermally controlled 3D printing using a mobile liquid interface," *Science*, **2019**, 366, 360–364.
10. Wahl, C. B.; Aykol, M.; Swisher, J. H.; Montoya, J. H.; Suram, S. K.; Mirkin, C. A. "Machine learning-accelerated design and synthesis of polyelemental heterostructures," *Science Advances*, **2021**, 7, eabj5505.

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Publications

1. Williams, G. D.; Lieszkovszky, M. C.; Mirkin, C. A.; Geoffroy, G. L. "Addition of the Os-CH₂ Bond in Os₃(CO)₁₁(μ-CH₂)₂ to Pt(PPh₃)₂ to Give the Spiked Triangular Cluster Os₃Pt(μ-CH₂)(CO)₁₁(PPh₃)₂. An NMR Investigation of the Fluxional Properties of Os₃(CO)₁₁(μ-CH₂)," *Organometallics*, **1986**, 5, 2228-2233, doi: 10.1021/om00142a010.
2. Davis, S. A.; Mirkin, C. A.; Terichel, M. "Lanthanide-Molecular Interactions in Solution Studied by FT-IR Spectroscopy," *J. of the Less-Common Metals*, **1986**, 126, 402-402, doi: 10.1016/0022-5088(86)90343-7.
3. Macklin, P. D.; Mirkin, C. A.; Viswanathan, N.; Williams, G. D.; Geoffroy, G. L., Rheingold, A. L. "Synthesis of Cp(CO)COPt(PPh₃)₂(μ-CH₂) and Cp₂(Co)₂Pt(PPh₃)₂(μ-CO)₂ from the reaction of Pt(PPh₃)₂(C₂H₄) with [CpCo(CO)]₂(μ-CH₂)," *J. Organomet. Chem.*, **1987**, 334, 117-128, doi: 10.1016/0022-328x(87)80043-8.
4. Mirkin, C. A.; Lu, K.-L.; Geoffroy, G. L.; Rheingold, A. L.; Staley, D. L. "Ferrapyrrolinone and Ferrazetene Complexes Formed from the Reaction of Fe₂(μ-CH₂)(CO)₈ with Phosphinimines," *J. Am. Chem. Soc.*, **1989**, 111, 7279-7281, doi: 10.1021/ja00200a068.
5. Mirkin, C. A.; Geoffroy, G. L.; Maklin, P. D.; Rheingold, A. L. "Synthesis and Characterization of the Heterobinuclear μ-Methylene Complex (CO)₄FePt(PPh₃)₂(μ-CH₂)," *Inorg. Chim. Acta*, **1990**, 170, 11-15, doi: 10.1016-s0020-1693(00)80402-8.
6. Mirkin, C. A.; Lu, K.-L.; Snead, T. E.; Geoffroy, G. L.; Rheingold, A. L. "Synthesis of Substituted Pyridinones from the Combination of Fe₂(μ-CH₂)(CO)₈ Phosphinimines, and Alkynes," *J. Am. Chem. Soc.*, **1990**, 112, 2809-2810, doi: 10.1021/ja00163a058.
7. Mirkin, C. A.; Wrighton, M. S. "Carbon Monoxide Dependent Solid-State Electrochemistry of Ferrocenylferrazetene: En Route to a Molecule-based Carbon Monoxide Sensor," *J. Am. Chem. Soc.*, **1990**, 112, 8596-8597, doi: 10.1021/ja00179a062.
8. Mirkin, C. A.; Lu, K.-L.; Geoffroy, G. L.; Snead, T. E.; Rheingold, A. L. "Fluorine-Substituted Ferracyclopentadiene Complexes with an Unprecedented Fluorine Bridge between Boron and Carbon," *J. Am. Chem. Soc.*, **1990**, 112, 461-462, doi:10.1021/ja00157a078.
9. Mirkin, C. A.; Lu, K.-L.; Snead, T. E.; Geoffroy, G. L.; Rheingold, A. L.; Haggerty, B. S. "Preparation and Interconversion of Binuclear 2-Ferrazetene and Isomeric Ferrapyrrolinone Complexes," *J. Am. Chem. Soc.*, **1991**, 113, 3800-3810, doi: 10.1021/ja00010a024.
10. Mirkin, C. A.; Oyer, T. J.; Wrighton, M. S.; Snead, T. E.; Geoffroy, G. L. "The Photochemistry of Binuclear Ferrazetenes: CO vs. Alkyne Insertion," *J. Am. Chem. Soc.*, **1992**, 114, 1256-1263, doi: 10.1021/ja00030a022.
11. Snead, T. E.; Mirkin, C. A.; Lu, K.-L.; Beckman, H. L.; Geoffroy, G. L.; Rheingold, A. L.; Haggerty, B. S. "Synthesis of 2-Ferrapyridine Complexes and their Use as Precursors for Substituted Pyridinones and Pyrroles," *Organometallics*, **1992**, 11, 942-958, doi: 10.1021/om00038a067.
12. Mirkin, C. A.; Valentine, J. R.; Ofer, D.; Hickman, J. J.; Wrighton, M. S. "Chemically Sensitive Microelectrochemical Devices: New Approaches to Sensors," *ACS Symposium Series on Biosensors*, **1992**, 487, 218-236, doi: 10.1021/bk-1992-0487.ch017.

13. Snead, T. E.; Mirkin, C. A.; Lu, K.-L.; Nguyen, S. T.; Feng, W.-C.; Beckman, H. L.; Geoffroy, G. L. Rheingold, A. L.; Haggerty, B. S. "Formation of Substituted Ferracyclopentadiene Complexes by the Reaction of Alkynes with Protonated Diferra- μ -Azaallylidene Complexes," *Organometallics*, **1992**, *11*, 2613-2622, doi: 10.1021/om00043a052.
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16. Chen, K. M.; Caldwell, W. B.; Mirkin, C. A. "Fullerene Self-Assembly onto (MeO)₃Si(CH₂)₃NH₂-Modified Oxide Surfaces," *J. Am. Chem. Soc.*, **1993**, *115*, 1193-1194, doi: 10.1021/ja00056a080.
17. Mirkin, C. A.; Premecz, J. E.; Ford, M. E.; Johnson, T. A. "Formation and Catalytic Hydrogenation of the Dimer of 1,2,3,4,5,7 a-Hexahydroimidazol[1,2- α]pyrazine," *J. Heterocyclic Chem.*, **1993**, *30*, 839-840, doi: 10.1002/jhet.5570300341.
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23. Shi, X. B.; Caldwell, W. B.; Chen, K. M.; Mirkin, C. A. "A Well-Defined Surface-Confinable Fullerene - Monolayer Self-assembly on Au(111)," *J. Am. Chem. Soc.*, **1994**, *116*, 11598-11599, doi: 10.1021/ja00104a062.
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25. Singewald, E. T.; Mirkin, C. A.; Stern, C. L. "A Redox-Switchable Hemilabile Ligand: Electrochemical Control of the Coordination Environment of a Rh^I Complex," *Angew. Chem. Intl. Ed.*, **1995**, *34*, 1624-1627, doi: 10.1002/anie.199516241.
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32. Mirkin, C. A.; Letsinger, R. L.; Mucic, R. C.; Storhoff, J. J. "A DNA-based method for rationally assembling nanoparticles into macroscopic materials," *Nature*, **1996**, *382*, 607-609, doi: 10.1038/382607a0.
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