I am Chad A. Mirkin, Professor of Chemistry and Director of the International Institute for Nanotechnology at Northwestern University. AMA about nanoscience, the commercialization of university inventions, and more!

AmerChemSocietyAMA [1] and r/Science AMAs[1]

[1]Affiliation not available

April 17, 2023

Abstract

Hello Reddit, I am a professor of Chemistry (as well as Biomedical Engineering, Materials Science and Engineering, and Medicine) and Director of the International Institute for Nanotechnology at Northwestern University. My research focuses on the development of methods for controlling molecular architecture on the 1-100nm scale and using such structures for inventing technologies that impact chemistry, biology and medicine. My research group is best known for the discovery and development of spherical nucleic acids (SNAs) as well as enabling techniques such as dip-pen nanolithography (DPN), polymer pen lithography (PPL) and beam pen lithography (BPL) – methods that allow scientists to "draw" and create patterns of extraordinary sophistication and complexity on a variety of surfaces using nanoscale pens and chemicals and biological materials as inks. In addition to my work at Northwestern, I am also a member of the President's Council of Advisors on Science & Technology (PCAST), and a member of all three National Academies. I also serve as an Associate Editor of the Journal of the American Chemical Society, the ACS' flagship journal founded in 1879. I'll be online at 11am EDT to answer your questions. Fire away! - CAM Editing links - ACS Signing off - fingers are worn out! Sorry I could not answer all of the questions, but thanks for a great discussion. Chad

the WINNOWER

REDDIT

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AMERCHEMSOCIETYAMA R/SCIENCE

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What nanotechnology research going on right now do you think will have the biggest impact in 5-10 years?

Sjmman

To me the subfield of nanomedicine, holds the greatest promise. Much of what is happening in electronics is more evolutionary rather than revolutionary -- still very important but the path was in place prior to the modern nanotech revolution. In medicine, however, certain nanostructures have proven to be useful for creating multifunctional probes and therapeutics that go well beyond what molecular systems can do. In the process, they are changing how we study, track, and treat disease.

Hello Professor Mirkin! I am currently studying chemistry but so far it seems like the only career paths available to me after college are those in pharmaceuticals or "research". How did you get into nanotechnology?

Crack_butt

I got into nanotechnology through chemistry. The field is fueled by advances in analytical methodology

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(tools that allow one to visualize and manipulate nano structures) and synthesis. Chemists are playing central roles in both categories. Stay in science and pursue what really excites you -- there are always job opportunities for motivated, passionate people, regardless of sub-discipline. As a nanotechnology/chemistry expert you can work in the chemical industry, the oil industry, consulting, intellectual property law, and the pharma industry. I got into the field based purely on interest - many of the techniques we currently use did not exist when I was in graduate school. We trained ourselves and in the process invented many new tools.

Dr. Mirkin, I'm currently a 0-year graduate student in materials science. It is my understanding that historically, the post-doc was supposed to be a stepping stone to a career in academia. You were notably opposed to the new executive order requiring employers to compensate more of their salaried employees for overtime work. You claim that the current culture is essentially a right of passage, but I believe that working near or below the poverty line is not a right of passage when it is lined with guilt requiring the PIs recommendation later on. Why are PIs not encouraged to apply for more funding to fairly compensate their researchers who may have a wife and children to support, instead of essentially holding their careers hostage?

Washingtonsbitch

It is a complex problem but there also is a limited amount of funding. I am for giving more people opportunities and helping them get career jobs that provide both fulfillment and high wages. I was simply making the point that when I did a postdoc, money was not my primary motivator and the experience was far more valuable long term than the the dollars I made. To me the problem is in the length of a postdoc, which has been stretched to unreasonable amounts in the field of biology. I encourage all of my postdocs to get done in 2 but no more than 3 years. From my perspective, the concept of a perm-doc is a bad one.

What are some examples of recently commercialized nano technologies?

nate

Research tools involving new forms of imaging, manipulating, and patterning nanostructures have been rapidly developed, commercialized, and disseminated around the globe. These have propelled work in the field. In addition, there are many more spanning the electronics industry (every computer chip) and catalysis (nanostructured particles) as well as less obvious ones in medicine, especially medical diagnostics. For example, the VerigeneTM system is a medical diagnostic tool used for point-of-care medicine in half the nation's top hospitals -- used to identify patients with blood stream infections, where a rapid response is required to inform patient care. Finally, there are quite a few nanomedicines in clinical trials for diseases spanning breast cancer, brain cancer, and psoriasis.

Hello Dr. Mirkin, thanks for doing this. Many "cool" things have been possible using nanotechnology, but years in, they seem to have over-promised and under-delivered. DNA origami, Carbon nanotubes (till graphene came along) etc. Every technical talk seems to rehash the same benefits even though many of these were promised at least a decade or more ago. What is your view on these and the chances of seeing tangible benefits in the marketplace in the near term?

rvathrwaway

I have a less cynical view. At the start of any new field, there is a lot of hope and hype. As scientists dig in, they often find it is more difficult than originally anticipated. After only 15 years, we have thousands of new technologies enabled by nano science. From our lab alone, there over 1800 commercial

products that can trace their routes to scientific advances at the university. I would argue that commercial development has been remarkably fast. We will see even more in the decade to come.

Current state of the art commercial CPUs have a ~14nm architecture, and bleeding edge CPUs as small as 7nm. It would appear that the progression of Moore's Law is doomed to come to a halt since CPU architecture resolutions are approaching the scales of atomic radii. A nanoscale structure such as a transistor or conductive trace requires at least a finite number of atoms to work, and you can't simply make the atoms smaller, so it would seem that soon we might be simply unable to make CPUs with any smaller architecture.

Do you see a path forward where we might be able to keep up with Moores law in the in the next 20-30 years?

Doctor_Anger

Of course, there is a physical limit -- the progress made to date is remarkable.

What is the difference between nanotechnology and just plain old ordinary chemistry? Sometimes I can't seem to see the difference but one term is fancy and the other is boring.

Forestman88

They are related. Nanoscience focuses on structures that are bigger than most of the molecular systems that the vast majority of chemists work on -- they are structures on par with the scale of biology. Chemistry often enables their synthesis or fabrication. These structures, because of their relatively large size, can have more complex properties, which open opportunities for new applications.

Hi Professor Mirkin! I was wondering if this PPL/BPL technology has any applications in the fabrication of semiconductor IC chips?

christophecricket

It could, long term. At present, it is most useful as a research tool for rapid prototyping and for creating combinatorial libraries that can be used for discovery purposes. Take a look at last week's edition of Science - a nice paper by Peng Chen from my group illustrates the power of the technology for such purposes. With the commercialization of PPL and BPL through TERA-print LLC, the impact of the technology will grow rapidly.

Dear Mr. Mirkin, how important is the university, from your point of view, you study chemistry in? Because I want to study chemistry too, it really is my true love when it comes to sciences, but due to my fairly bad financial situation I have to start at a smaller university in Germany. Someday I really want to get into research, obviously not immediately, but some time in the future. Do you think a poor choice of university will compromise me? How are the chances of switching to a bigger university if I show good results and a good attitude when it comes to work? And one more: Which "direction" (biochemistry, polymer chemistry, etc.) of chemistry do you see the most potential in? I for myself am interested in multiple, but first I will make my Bachelor and then see what I'll do for my Master. Thank you for your time if you manage to read this and I have seen some of your work and read about it and it's really impressive.

TheChemist33

Go to the best university you can afford, do well and look to move up. One can succeed regardless of where one starts. Some of my best students have come from lesser-known places, but they have the passion and drive to compete with the best. You may want to get some experience in the US for grad school.

I often think of nanoscience as robots on a subcellualar or even submolecular level. What is nanoscience, and on what scale does it occur?

JavaPython_

The robotic aspect is a vestige of science-fiction. The real opportunity in nanoscience comes from the very simple observation that all materials are different when miniaturized to, or restructured on, the nanoscale. This means everything old, when miniaturized, becomes new and different, and the discovery and classification of those differences can lead to technological solutions to some of our most pressing problems. Bulk gold when miniaturized to the 10 nm length scale is red in color and becomes useful as a diagnostic probe or dye. Semiconductors when miniaturized have tailorable band gaps. DNA when organized on the nanoscale into spherical structures can naturally enter cells and be used for intracellular diagnostic and therapeutic purposes. The list goes on.

So at the University in Groningen in the Netherlands we have a commericialisation unit for developing the inventions done at the university. They even started with letting business studens try to make a business case around patents they have. Is this something other universities do aswell, and what do you think about this?

TheMadBarbarian

It is a good model. We use a version of it at Northwestern University.

What are your thoughts about the career path of "inventor"? My kid tells me that some of his classmates said they wanted to be inventors after learning about some of the founding fathers in school... How realistic is that?

threwaway4244

I would recommend being a scientist/inventor. A full time job as an inventor alone is tough.

What ideas or facts of nanotechnology blow your mind? The kinds of things that help one get out of bed in the mornings? :)

natellama

I like to believe that the idea of merging advances in nanomaterials synthesis with biological pathway understanding has the chance of stomping out disease as we know it.

Can you discuss the viability of using nano silver to control the spread of "Super Bugs" in the hospital setting? I learned about this here and have been interested in it ever since but ironically, I do not see it used in any real world public applications and have often wondered why.

Bkeeneme

It is my understanding that it is used in certain carpets, paints, and even on hearing aids to avoid bacterial buildup.

What does work on the President's council of adviors on Science and Technology entail?

sarahbotts

We advise the President through policy reports on almost any topic where science and technology research can impact the nation, spanning education, energy, the internet, defense, climate, and medicine. Recommendations are implemented via the various agencies (DOE, DoD, NSF, NCI, NIH, NASA, etc.)

Hello Dr. Mirkin! I just want to say I'm a big fan. I took a nanotechnology class my first year in college and did a paper on DPN and AFMs which cited your research group extensively. I loved how simplistic the idea of an AFM depositing ink is and was impressed by how precise the ink deposits are.

My question is about the biotechnical applications of DPN. How advanced are the protein patterning applications and what would be the real world applications for it?

Thanks for taking some time to answer!

Dr_Lobster

Anything ranging from controlling stem cell differentiation to the development of miniatured and massively multiplexed biosensors.

Once we have truly failed to curb global emissions, do you think there's any chance the world's scientists could come up with a way to scrub carbon from the atmosphere in a large scale way? Is that even vaguely feasible?

isaidthisinstead

A tough problem. I don't rule it out because scientists do remarkable things. However, the scale and diffuse nature of the problem make it particularly challenging.