

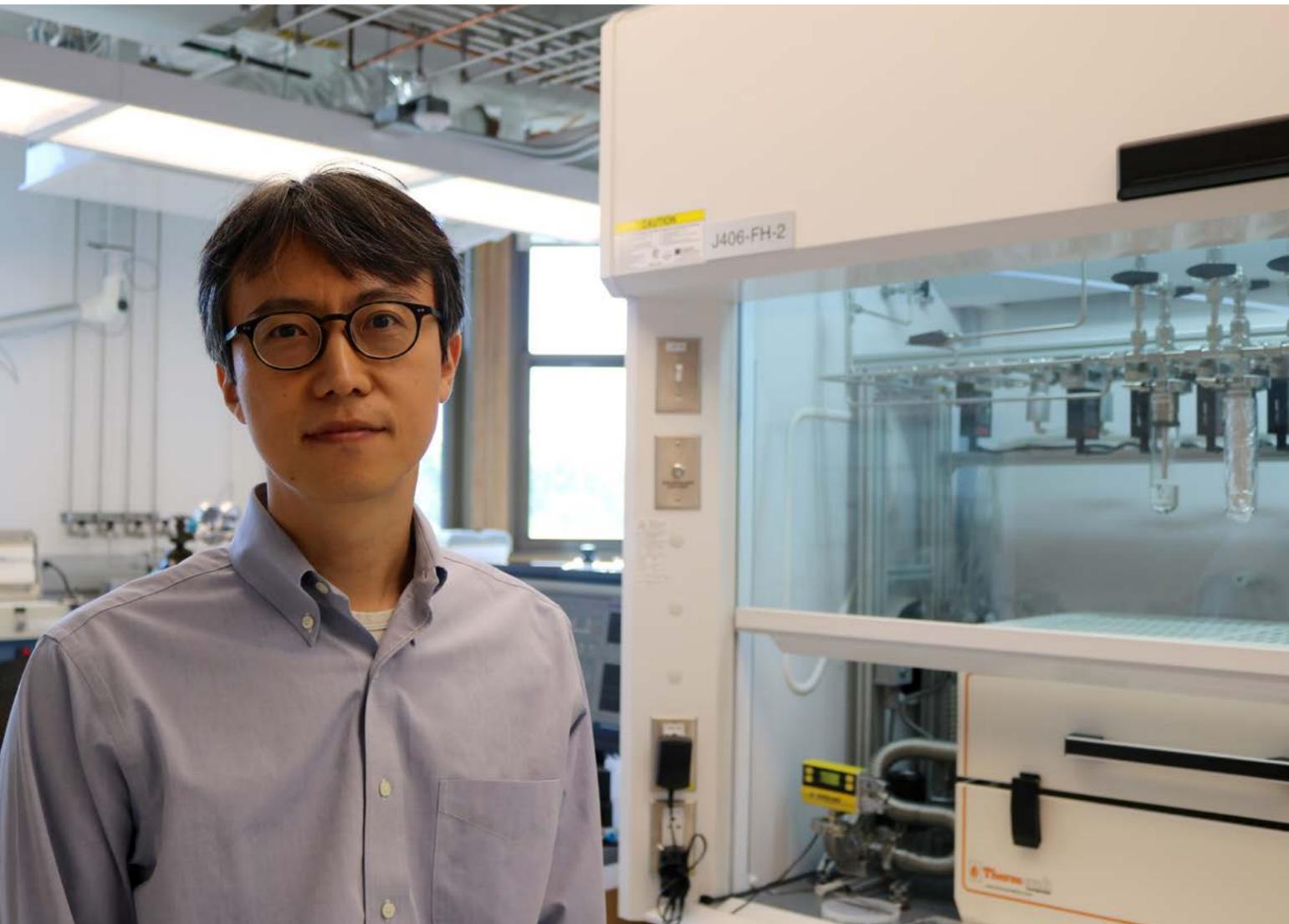


## Celebrating Creativity and Collaboration

*Dmitri Talapin and Jiwoong Park work together  
to revolutionize information technology*

# Material Revolution

Jiwoong Park engineers atomically thin integrated circuits using transition metal dichalcogenides



Humans have left meaningful marks in stones and bones for millennia. However, the invention of paper about two thousand years ago was the revolution that founded our civilization, declares Professor Jiwoong Park, who joined the faculty of the Department of Chemistry in 2016, after a decade at Cornell University. This material shift made means of disseminating information “cheaper, scalable, and manufacturable,” he says. “If you think about the big change from tablets to paper, it’s quite amazing, right?” Drawing an analogy to his investigation of atomically thin integrated circuitry, Park makes a bold claim for the potential impact of his work: “Modern information technology, as allowed by the [silicon-based] semiconductor industry, is the equivalent of the tablet.” Working with compound materials that are just three atoms thick, Park and his group are in hot pursuit of the next material revolution. “If silicon is our modern day tablet, what is our modern day paper?”

Park’s interest in atomically thin materials was piqued by the work of Andre Geim and Konstantin Novoselov, whose extraction of a one-atom-thick layer of carbon in the form of graphene in 2004 later garnered a Nobel Prize in Physics. Park’s group began work in this area in 2009, after reading a paper in *Science* about the large-scale synthesis of graphene. “That was really powerful work that showed that atomically thin materials could be grown on a big scale,” he explains. “We thought that this atomically thin material platform had tremendous opportunities. And nature gives you tremendous options,” he notes. “Carbon is a great example. Two materials formed from carbon are graphite and diamond. You can see the difference—diamonds are like silicon in terms of their structure, a three-dimensional network, very strong. But diamonds are not the most stable form of carbon. Graphite is the more stable form, made out of many layers of graphene. We joke that diamonds are not forever—graphite is forever. But you cannot make a whole industry out of pencils!”

After several years studying synthetic graphene, Park’s group now focuses on transition metal dichalcogenides—including molybdenum disulfide, tungsten ditelluride, molybdenum diselenide, and other compounds—which they are able to grow into stable wafers a few inches in diameter but only three atoms thick. Just as generations of engineers have developed methods of doping and patterning silicon to achieve precise circuits with excellent spatial resolution, Park and his team have focused not only on perfecting a technique of metal-organic chemical vapor deposition to produce a uniform monolayer of their desired material, they have also turned them into successful devices by doping and patterning them. “The most surprising aspect of our material,” says Park, “is that we peel [a layer] off and stack another one on top, then peel and stack another one on top, and so on, so that we can build a much more complex material or device that is engineered layer by layer.”

## If silicon is our modern day tablet, what is our modern day paper?

About future directions, however, Park and his coworkers have little interest in simply making devices smaller. “When you work on preexisting applications, you probably end up being successful,” he says. “In fact, there are many talented people working on improving what already exists, but at the same time, there are people working on what does not yet exist. And we love to do the latter.”

The University’s investment in science has played a strong role in encouraging Park to bring the next phase of his research to Chicago. “The spectrum is really broad here,” Park says, citing colleagues in Chemistry and Physics, as well as the IME and the JFI, where he holds joint appointments. “I really cherish the number of people we interact with,” he says. “The nature of my research is based on active and new collaborations. It’s important for my research to connect to new ideas and new science, because we work at the interface between chemistry, material science, and physics. And, of course you don’t want to work with just anyone, you want to work with great minds and ideas.”

The future of Park’s research is both indefinite and alive with possibility, and his approach to the application of his atomically thin circuits is cautious but ambitious. “We sometimes put ourselves in the minds of the people who made paper for the first time. What were they thinking? They probably didn’t expect to see books in everyone’s homes many thousand years later. And certainly they didn’t think about civilization developing, catalyzed by it. We are not thinking specifically about building a new application—rather, we are thinking about building a new platform that allows people to build amazing things in the future. People may look at big things like skyscrapers or networks of airports or the Internet. If you look inside your cell-phone, and if you imagine how people made circuits and wireless communications possible in this tiny device, it’s an amazing thing! When people first made silicon devices, they probably didn’t imagine anything like what we are seeing. Our question is, what if we could make these amazing circuits that are really, really thin?” (ICH)



## From Surface Science to Circuit

Dmitri Talapin and coworkers develop new method for patterning nanomaterials

Much debate exists over what machine or concept deserves to be considered the first computer. Some point to the abacus, the counting machine that predates the existence of written numerals, others to Charles Babbage's 1837 plan for an analytical engine that could be used to perform logical processes communicated through punched cards. Though Babbage's machine was never built, it exhibited characteristics that would later be developed in Alan Turing's 1937 theoretical machine that could execute any task communicated by algorithm.

While electromechanical computers were built as far back as the 1940s, these unwieldy machines depended on mechanical relays driven by electric switches to perform calculations. The first all-electronic digital computer, the ENIAC (Electronic Numerical Integrator and Computer), exhibited revolutionary calculating speed but also substantial limitations: it required manual rewiring for each new program, and the only model ever built weighed in at a hefty 27 tons.

Innovations in hardware—especially the transistor and the integrated circuit, or microchip—allowed such behemoth machines to evolve into the pocket-sized electronics we have today, starting when Intel first condensed the entire central processing unit of a computer into a few integrated circuits in 1971.

"Integrated circuits are one of the most impactful discoveries of the twentieth century," says Dmitri Talapin. "A process called photolithography makes all modern electronics possible by allowing us to build tiny transistors and put billions of them on the same chip at a very modest cost."

Photolithography includes the application and subsequent removal of a light-sensitive polymer coating that enables patterns to be printed into a semiconductor substrate through exposure to light. In the July 28 issue of *Science*, the Talapin lab showed how to use photolithography

Chemistry is the science of making and breaking chemical bonds. These are elemental steps—here we made a new bond; here we broke one.

for patterning various nanomaterials. Nanomaterials have emerged as a new class of building blocks for electronic and optoelectronic devices that have properties that traditional silicon does not, such as emitting colored light or detecting infrared photons. Talapin's new technique, Direct Optical Lithography of Functional Inorganic Nanomaterials or "DOLFIN," allows nanomaterials to be integrated with silicon chips. This approach can also be used as a shortcut that eliminates the need for polymers in photolithography.

"It's a very versatile chemistry," Talapin notes. "It works with materials that could not previously be efficiently processed with photolithography, including technologically important nanomaterials such as quantum dots"—tiny semiconductor crystals that are used for a wide variety of applications, including LEDs, light detectors, solar cells, and more. "It broadens the kind of materials that can be precisely patterned and used in complex manufacturing processes," he explains.

Talapin's nanomaterials change solubility upon exposure to UV light. A solvent then locally dissolves the illuminated region. They have also designed a different solvent that selectively dissolves areas that have not been exposed to light.

Talapin attributes this useful discovery to a decade of research studying the surfaces of nanomaterials, fundamental research that combines surface science with molecular inorganic chemistry. "Chemistry is the science of making and breaking chemical bonds. These are elemental steps—here we made a new bond; here we broke one. We did a lot of groundwork when we designed previous generations of ligands. Now our mode of operation has moved from discovery to engineering. We know what we want to accomplish, so we can dig into chemistry and surface science books to look for ingredients to make it happen."

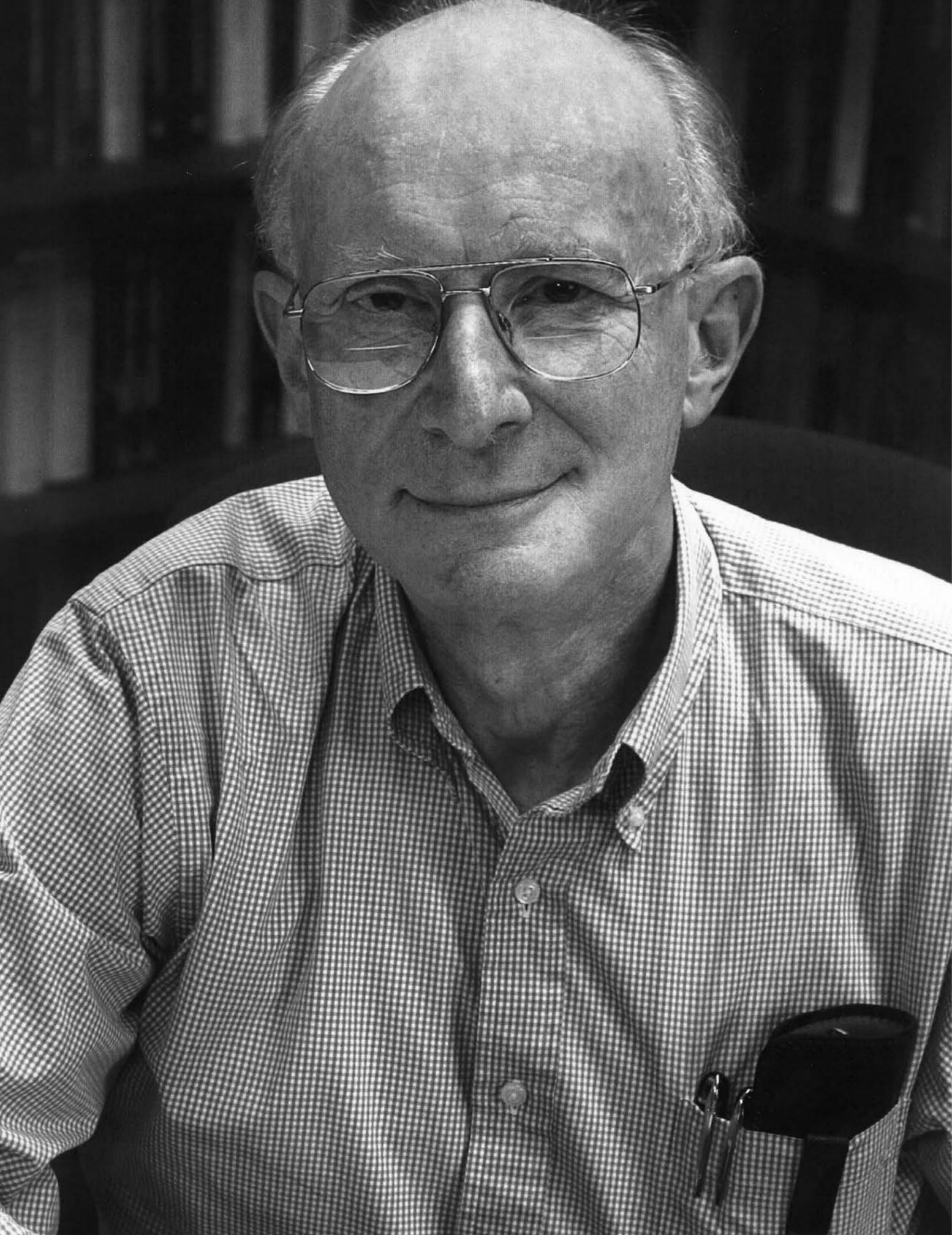
"It's a natural frontier to me," he says. "I had been interested in this kind of molecular and material science for a long time, and I had particular thoughts about understanding electronic transport and thermal conductivity in nanoscale granular media. The more we learned on the fundamental side, the more opportunities we saw for applications."

In keeping with Talapin's passion for interdisciplinary research, he declares that opportunities to collaborate at the University of Chicago are instrumental to his work—including, for the first time, a joint graduate student with Jiwoong Park. "We are learning how to mentor a graduate student who works truly between two groups. I hope such students will be able to bridge the gaps between different communities disseminate knowledge within our communities and step into areas where not many others are capable of working."

In addition to purely academic endeavor, Talapin regards his new technology as the foundation for a business plan—and another opportunity to teach. "The role of the modern university is much broader than it was a hundred years ago. Previously fundamental and applied science were often distant from each other. Now the situation is different—there is one continuous spectrum of activities that connect fundamental science with applied and translational research," he says. "Our students should have an opportunity to learn not only math and science but also to understand engineering and entrepreneurship. We invest millions of taxpayer dollars in our research, aiming at advancing fundamental science, and occasionally learn something that can lead to novel technologies. In those cases, the discovery may be turned into useful products."

In fact, he argues, startups that emerge from academic discoveries play an essential role in the technological ecosystem. "Startups fill a niche between what is too applied for academic labs and too risky for big companies. To some extent, startups translate fundamental research into language that can be understood and appreciated by industry leaders. We are trying to build an entrepreneurial culture here. It's a new experience for us."

Nevertheless, Talapin remains committed to curiosity-driven research. "It would probably negatively affect our mission as an educational institution to turn my lab into a startup. I would like my lab to stay focused on fundamental problems and hopefully outsource translational research to the companies started by students and postdocs—that would be ideal!" he says with a smile. Even so, the aims of each are not at odds: "The more we expose our students to different options, the higher the chances will be that they will find their path and their passion." (ICH)



# Rice on Colloids, Collaboration, and the Department of Chemistry

Stuart A. Rice converses with Irene C. Hsiao on 12 July 2017

Stuart A. Rice, Frank P. Hixon Distinguished Service Professor Emeritus, is the author of over 700 papers on topics ranging from the statistical mechanics of fluids to the structure and dynamics of molecules adsorbed on surfaces. He has received numerous honors for his work, including the National Medal of Science and the Wolf Prize. A Fellow of the National Academy of Sciences, the American Academy of Arts and Sciences, and the American Philosophical Society, Rice has also authored textbooks and edited *Chemical Physics Letters* and *Advances in Chemical Physics*. Over the past six decades at the University of Chicago, Rice has served as the Director of the James Franck Institute, Chair of the Department of Chemistry, and Dean of the Physical Sciences Division, and mentored over one hundred graduate students.

## **What was the department like when you first came to Chicago?**

I came here 60 years ago, in 1957. The distribution of fields represented in the department was a little different than it is now. There was a large component of cosmochemistry, which was invented here by Harold Urey and his colleagues—the chemistry of the planetary system, of the universe. Like most departments in other universities, analytical chemistry, which had been a major field for many years before the war, was on its way out. The department was not particularly devoted to natural products chemistry, which was quite common in other places. Here the orientation was more towards physical organic chemistry, that is, applying physical principles to understanding organic reactions, devising new reactions using physical principles, and so on. Materials chemistry, which didn't have that name and didn't exist sixty years ago, is now a major part of the department. As the science has shifted, people have moved in the direction of the shift or sometimes led the shift, but the core of chemistry and the theme that chemistry pervades many other fields have remained central to the department.

## **Did you have a strong hand in shaping the department?**

To the extent that the people I have helped hire have developed new lines, yes, but no, in the sense that I never looked for people to go in a

particular direction. I looked for the people I thought were the smartest, the most original, the most inventive, and so on, no matter what they were doing. The reason I was able to do this was that the atmosphere when I came and for quite a number of years after encouraged faculty to always be on the lookout for somebody outstandingly smart and innovative.

Nominally speaking, we always had a limited sized faculty. That limited size was interpreted to mean that if an individual of really exceptional quality were discovered, somehow we would make space for him or her. The faculty size worked out to be on the average fixed, plus or minus one, but the attitude wasn't that it was fixed. The opportunity to make an appointment did not depend upon there being a specific opening in that area. If there was a need in an area, you pursued individuals with that expertise, but you also kept your eyes open for others you stumbled across that had other expertise. If they looked attractive, you might try to appoint them.

That changed as the financial structure of the university changed. Even though individual faculty [still] make suggestions for appointments, it's within a framework that's different than previously, which was not so much a framework as a hunting license.

## **Don't you think that when you achieve a certain mass of, say, physical chemists, they would tend to know mostly the other chemists in that field?**

Yes and no. A lot depends upon your attitude and what you think is the role of university and what kind of environment you want to construct. My personal view is that the university has multiple roles. Amongst those roles are the cultivation of new faculty and the creation of an environment in which both new faculty and old faculty thrive. That's not what I'll loosely call the "Harvard" or "eastern" university tradition, in which the measure of merit is how famous the individual is, so you tend to hire older people who are already accomplished.

I'm not saying that's bad, but it's a different view of what you want. So we would see the very smartest young people, but if you do that, the other piece of the environment, which I found entirely different from Harvard

and Yale, is that you have to then say, “Not only do we think you have the talent and can succeed, it’s our responsibility to help you succeed, and if you do, then you get to stay.” The eastern universities I was educated in were rather different. They tried to pick the smartest young people also, but the chances they had for promotion were small because the focus on the permanent positions was, “Who’s already famous?”

There, the senior faculty paid relatively little attention to the junior faculty—they could or could not take risks, but the level of psychological and emotional support for the younger people at that time was entirely different than it was when I came here. It wasn’t so much the financial part, although I think the financial part was also better here, but psychology of being part of the enterprise, as opposed to being ancillary to the enterprise, that was different.

#### **Did you feel that as a young professor?**

Oh, yeah! Very much so! It was evident right from the beginning that the senior faculty were out to help me to do what I wanted to do, and as a result, I undertook things that I had never come remotely close to doing and had never done, and people encouraged me and said to me, “Don’t play cautious. Don’t continue doing what you were doing before. Don’t do things that are easier to do because they can get done. If you think that this is interesting, go for it! And we will help you.” That’s a huge psychological difference!

#### **What were those things?**

They are modest in some respects. When I was a graduate student, I did a mixture of theory and experiments on nucleic acids—biophysical chemistry-type experiments. The first experiments I did here were with low temperature liquids: liquid argon, liquid neon, and so on. I had never been anywhere near anything like that before! But I had ideas about how energy and matter are transported in liquid, I wanted to do experiments, and I was encouraged and helped to do them. I probably could have struggled through without the assistance, but it would have been much harder, and with a higher probability of failure. In general, the attitude was, “Swing for it!”

#### **Who were your mentors?**

Lothar Meyer, who has since died, helped me with low temperature experiments. He principally, and the machine shop—at the time we had a wonderful central machine shop—which later developed into collaborative work.

#### **Do you feel you’ve had a similar relationship with younger faculty?**

I hope so. There’s a line between intruding and helping. I try to help without intruding, with suggestions for experiments or for theory. For many years I supplied equipment—I was sort of the equipment storehouse for a lot of people. I would help them with suggestions for experiments or for theory. I hope I played a similar role because [others] helped me a great deal.

A very large fraction of what I have worked on over the years has arisen because of my contacts with people in physics and, to a lesser extent, geophysics.

#### **What do you work on now?**

Now I’m working only with undergraduates, so the laboratory work we are doing is limited by our equipment, which is aging. We’ve been working almost entirely on confined liquids, liquids which are constrained to occupy dimensions comparable to the size of the molecule. In order to do this, the liquids that we use are colloid suspensions, in which the particle sizes are microns. A micron is a thousandth of a millimeter. On the size of my hand, that’s small, but a typical molecule would be ten angstroms or less in diameter, which would be a thousandth of a micron.

There are several reasons for studying these suspensions. They have some very interesting properties that are unique to the colloidal state. But they also are surrogates for a molecular system. There are theorems that relate the equilibrium properties of the colloid systems to the equilibrium properties of molecular systems, and the colloids are big enough that, with modern microscopy, you can actually see the individual colloids. So that means you can construct mechanical pictures of their motion and how their motion affects their properties from optical microscopy.

To the extent that theorems exist that translate the properties of colloid suspensions into the properties of molecular systems, you then also learn about molecular systems. In addition, because you can make all kinds of colloids in different shapes with nanotechnology, you can investigate questions that are intellectually interesting but that you can’t do with molecules. For example, you can make little spheres, little cubes, little octahedrons, squares, pentagons, heptagons, and you can study how they pack. You can’t do that with molecules because the molecule has a shape that is inherent to the chemical

bonding, and you’ve got what you got! And if you want to know how squares pack, you can’t do that with molecules, because there are no real molecular squares.

There are things which you can learn about ordinary matter by analogy by studying colloids, and there are things that are unique to colloids that do not translate to molecular systems. By the way, colloids are ubiquitous in nature; almost everything you touch has some colloidal component.

#### **What is a colloid?**

I can give you a definition that sounds precise but has some ambiguity. The colloidal state of matter consists of aggregates and particles that are, ballpark, in range of about a tenth of a micron up to ten microns in size. So these colloid particles contain many molecules but are themselves small on the human scale. You can make crystals of them. Other versions are aerosols. Others are glasses. As for the shapes of the colloid particles, I presume there are some limits, but they can take many forms. They can be collectively disordered, partially ordered, or ordered. We work across the spectrum because one of the things we’re interested in is how the collective order emerges from the disorder. That turns out to be a subtle question which is different depending on how many dimensions the matter is contained in.

In the real world, since everything is three-dimensional, when you talk about something that’s two-dimensional, you have to say it’s effectively two-dimensional but with boundary conditions. It’s contained in something, and it has to be held somehow. And the boundaries matter. Imagine a thin film. Whether suspended over a hole or lying on a surface, it’s bounded by something above and below. That’s the three-dimensional world. The film can be constrained to move in two dimensions, but how it moves depends upon how it interacts with the boundaries. So the thin film is never really two-dimensional in our world, but it can approach that limiting behavior.

You can study the motion of individual particles—how fast they move around, what their organization is, whether they order in a regular pattern at a certain density. You can study whether or not they form complicated patterns or simple patterns. You can increase the thickness of the container a little bit and see what happens when you make two layers instead of one layer. You can do all kinds of things like that.

#### **How did you become interested in colloids?**

Like many other problems I have studied, I sort of stumbled into it. There’s a theorem dating back to the 1930s, proved rigorously in the 1970s and early 1980s, that if you try to make a two-dimensional array of molecules, it cannot be a perfect crystal because at any temperature other than absolute zero, there is enough motion that the long-range correlation between the positions of the particles is lost. What characterizes a crystal is that if I know the [location of an atom], and I know the spacing of the crystal, I know the location of every other atom in the crystal, so to speak, “what’s over there.” That’s

true in three dimensions. In two dimensions, it turns out that at any temperature other than absolute zero, there’s enough motion that the uncertainty in the distance between atomic positions becomes greater than the lattice spacing, so you can no longer say you have a crystal. The uncertainty in particle separation grows slowly so there is local crystal-like order in the first few neighbors of a particle.

It turns out this theorem has an interesting consequence: in three dimensions, essentially every known substance—salt, sugar, metals, whatever—melts from the solid to the liquid accompanied by a change in the density. Ice is less dense than water; for most materials, the solid is denser than the liquid. But in any event, there’s a change in density upon melting no matter what the matter is. In three dimensions, it doesn’t seem to matter what the molecular interactions are. In two dimensions, it turns out that because of this loss of long-range translational order, the way a substance melts is different from that in three dimensions. In two dimensions, there’s the possibility for melting to pass through a distinct phase that is between the partially ordered solid and the disordered liquid. The observation is that the partially ordered solid is characterized by having long-range order in the angular arrangement of the particles and very slowly decaying order in the separations of the particles, and in the liquid there is order neither in the angular arrangement of the particles nor in the separations of the particles. So in principle you can imagine a phase with very slowly decaying order in the angular arrangement of the molecules and no order in the separations of the particles. This new arrangement is called a hexatic phase.

#### **When you say “decaying order,” do you mean you can’t predict where anything is?**

I mean that the particle arrangement is not regular in some sense. Let’s take pennies in a plane. You can pack six pennies around a central penny. If extended to make a perfect crystal of pennies, you would have angles between three pennies in a triangle of sixty degrees, and the penny centers would be spaced regularly. In the real two-dimensional case, you preserve the angles of sixty degrees, but you lose the regularity in center-to-center translation. So the solid is partially ordered but not fully ordered. And in the liquid, you lose the angular order and the translational order. In the phase intermediate between them you have lost the translational order, and you have partially lost the angular order, which decays very slowly. It’s a new phase that has been studied experimentally primarily using colloids. It’s still not a fully settled question, and there are still major issues concerning when the hexatic phase occurs, that character of the transitions to the liquid and partially ordered solid phases, its dependence on the particle interaction, and more. Two-dimensional melting turns out to be very subtle, unlike the three-dimensional case. It appears that, depending on the potential, you can get all kinds of wacky things happening, and that’s what we’re looking at. I’m interested in the structure and how the structure changes for a given colloidal situation.



### **So you don't have a preference for order over disorder?**

No. We're examining and trying to understand the physical processes involved in two-dimensional phase changes. And because of the subtleties and complications of three dimensions, when boundaries matter and when boundaries don't matter, that's what I'm interested in. Moreover, how the colloids in these restricted situations move; that is, whether the motion has simple characteristics or not, is also of interest.

For example, you can make a channel that's only ten percent bigger than the particle size, so they can't pass each other. They have to move in a row. That's very different from two- and three-dimensional motion. The particles can't pass each other, so how do they move? They're in continuous jerky motion, so-called Brownian motion. If you're in two and three dimensions, the mean square displacement of a particle undergoing Brownian motion grows linearly with the time. In one dimension, it grows with the square root of the time.

### **If I were better at math, what would this indicate to me?**

It's a completely different behavior. So now let me make a ribbon that is two lines of particles wide, three lines wide, four lines wide. When do I go from one behavior of the mean square particle displacement to the other? That's something you can study with these colloids.

### **How do you map all this?**

Basically what you do is learn how to follow particles and reconstruct from the trajectories of the particles these macroscopic behaviors.

### **Can you label them?**

You almost can. The particles move relatively slowly, so from image to image, you can identify the same particle. If your sequence of images is closely spaced enough that you know the particles are moving less than a particle diameter, you can optically label them.

### **How slow is slowly?**

We typically take pictures every 30 milliseconds, or so. That's slow on any kind of atomic scale. We probably could take pictures on the millisecond but we don't have the apparatus.

### **That sounds beautiful!**

Oh yeah, they're rather neat!

Anyway, most of what we're working on concerns various aspects of the properties of confined fluids for which the colloidal suspension acts as a vehicle, a surrogate for the molecular liquid. What I really want to know is how these ideas apply to molecular liquids or solids. For equilibrium properties, there is a theorem by McMillan and Mayer.<sup>1</sup> Suppose you have two particles in a vacuum. I could attach a spring to each one and measure the force required to move the particles towards each other. Using ordinary mechanics, that force could be converted into an effective potential energy of interaction whose slope gives me the force between the particles. Now let me repeat the experiment with

all sorts of other particles around the pair I am interested in. I still have the springs attached to the particles. It's fairly clear that the force required to change the separation of the pair will be different in the two cases, because as I do this, everything around the pair rearranges. In this mixture that force can be converted to an effective potential energy that depends on what the surroundings are like; it's called the "potential of mean force." And what the McMillan-Mayer theorem says is that, in a mixture, if you substitute the potential of mean force for the vacuum potential, the formal mathematics looks the same for a dense liquid and a dilute gas. So what that means is that the properties of the colloid suspension can be mapped onto those of a simple liquid. So that way the structure and everything else is translatable from one to the other.

### **When did you become emeritus?**

I was seventy in 2002, so it must have been 2003. Federal law requires that you draw your retirement funds when you're seventy and a half. You can continue working, but you have to draw the pension. The government wants its taxes. Since my birthday is January 6th, if I retired as of the end of the fall quarter of 2002, I'd have to withdraw a whole year of pension in a year when I already had salary.

### **So you retired purely for legal reasons?**

No, I was ready to retire because I felt that that was a time when we were being restricted in appointments, and, if I retired, then an appointment would be open for the department. That was a primary driver.

### **What happens when you retire—do you have to give up your lab?**

It's a gentleman's agreement that's determined by your activity and your health. If you are able to continue research, you can keep your space until it is needed. And if there is a need for space, even if you are continuing to be active, you should be willing to give up space to

a new appointee. It works very well. We have quite a number of emeritus faculty who are fully active.

### **So could you have a graduate student?**

Yes, but I have no external grant money.

### **Could you apply?**

I could apply, but in general you will find there is a practice that is illegal that discriminates against grants to older faculty across the country. I'm not unique. And it happens sufficiently frequently that, when push comes to shove, federal agencies want to give the money to younger people. It's not necessarily a bad idea, but if you say that what you want to support is what you perceive to be the best science, irrespective of the source, you ought to respect that goal, and if older scientists can compete, then they ought to be funded.

### **You have also been an active member of the JFI—what exactly is the relationship of the Institute to the Department?**

In 1945, there were two things that came into confluence: the need for new laboratory facilities at the university and the obvious success of the Manhattan Project as a collaboration of people with different backgrounds. That promoted the notion that you should create organizations that mixed the conventional disciplines, and that's what the research institutes were designed to do. But what do you do about the classical disciplines? How do you deal with education? So the departments were kept as the educational centers, and the research centers had no teaching role per se. At the very beginning, members of the Institute didn't teach at all. But that only lasted a year or two before it was realized that was a hopeless situation. The idea remains today that the Institutes are intended to promote interaction between people with different backgrounds, to stimulate different kinds of ideas and approaches. And it works! A very large fraction of what I have worked on over the years has arisen because of my

contacts with people in physics and, to a lesser extent, geophysics—just meeting in the hallway, talking about the kinds of things that wouldn't happen if you weren't mixed up has major serendipitous effect.

### **Is it true that the chemists used to eat lunch together every day?**

A third to a half of the department would meet every day at the Quadrangle Club for years. I used to go every day for 35 or 40 years.

### **Do you miss it?**

I do. But people were falling away, and my physical balance has become very bad. If I were to go now, there would likely be no one there.

### **Do you think there is actually a division between chemistry and physics?**

I think that people who are educated as physicists think of themselves as different than people who are educated as chemists. The focus in chemistry is understanding molecules, how to transform one molecule into another, how matter behaves, and so on. That focus is shared in many ways with materials science and also is shared in many ways with physics. But an absolutely fundamental part of chemistry is how you synthesize new molecules—that's not physics. An absolutely fundamental part of physics is discovering new laws of nature, which is not a part of chemistry. So there will remain core goals and subjects in physics and chemistry that don't overlap. But it would be hard to say if a lot of what I've done is either chemistry or physics. And I think that's true of physical chemistry, that's true of material science, molecular engineering, computer science, etc. Different fields of study are now mushed up.

### **How did you become interested in chemistry?**

I don't know. I think probably I became a chemist instead of a physicist because I had an outstanding freshman chemistry experience in college, and not such an experience in physics. But I don't really remember. I started out in college nominally as a premed student, and that lasted about six weeks before I decided that wasn't my style. And then it was chemistry or physics. But I couldn't say there was any decision point. Chemistry just appealed to me.

### **No regrets?**

Not particularly. I can't know what would have been otherwise.

### **Do you have any advice for young chemists?**

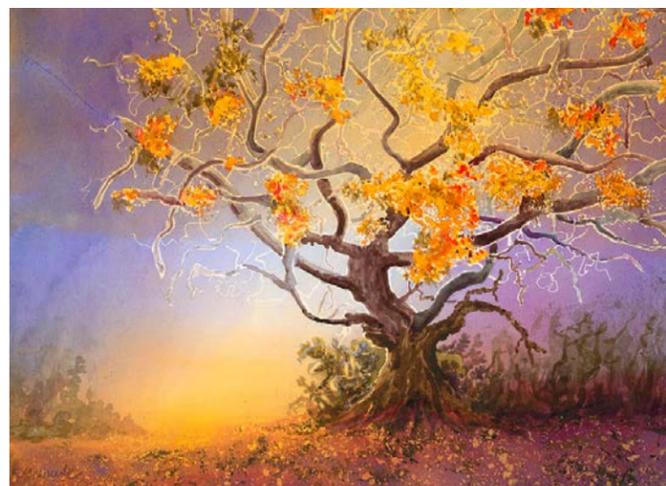
Try and find something you're really interested in, because that's what makes life worthwhile. If you try and do something you're not interested in, you'll be unhappy in one way or another.

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<sup>1</sup>William G. McMillan, Jr. and Joseph E. Mayer, "The Statistical Thermodynamics of Multicomponent Systems," *Journal of Chemical Physics* 13: 276 (1945).

## In Memoriam: Danute Nitecki

Photo by Daniel Straub



Danute Emilija Nitecki, née Šurkus, was born in Lithuania on April 22, 1927. Her family fled the second Soviet occupation at the end of World War II and spent the next six years as refugees in Austria and Germany. Dee, as she was known, graduated from Ecole des Arts et Métiers in Freiburg im Breisgau, Germany, where she focused on textile art, painting, and ceramics. In 1950, she emigrated with her family to the US, where she and her family initially worked in the stockyards of Chicago. Though her work there was difficult, she was said to remember the time with gratitude, noting that she no longer feared the Siberian labor camps that had taken the lives of many relatives and friends. Fluent in at least six languages and a polymath gifted in science as well as art, Nitecki entered the graduate program in chemistry at the University of Chicago in 1951, where she received an SM in 1956 and a PhD in 1961. During her studies, her mother, Emilija, also worked for the Department as a tech in the lab of Harold Urey. Nitecki's doctoral research, "Synthesis of Cyclo-L-Tyrosylglycylglycylglycyl-L-Histidylglycyl," was carried out under Kenneth Kopple in organic chemistry. Two *JACS* publications resulted from her work at Chicago.

Following graduation, Nitecki moved to the West Coast, where she worked in peptide chemistry, first as a researcher in the Department of Genetics at the Stanford University Medical School and then for nearly 20 years at the UCSF Medical Center, where she

She contributed to over a hundred scientific publications and is a co-inventor on nearly 50 patents.

explored various biomedical areas, especially immunology. In 1982 she entered biotech, first working for Cetus Corporation (later acquired by Chiron) and then for Berlex. Nitecki contributed to over a hundred scientific publications and is a co-inventor on nearly 50 patents. She continued to publish well into her seventies, with a final paper appearing in 2007. While she immersed herself for decades in biomedical research, she pursued other interests just as passionately. She regularly surrounded herself with friends of many ages and talents, renting out rooms in her Berkeley home to graduate students and visiting scholars, and sharing a large meal every Friday evening with anyone who wished to attend. Friends remember her home as a hub of sparkling conversation and communal activity.

In the late 1980s, Nitecki resumed drawing and painting. Her artistic talent was quickly evident, and her artwork was shown at numerous juried art exhibitions, winning several awards and ribbons. One of her botanical paintings of *Heracleum lanthanum* was selected for the biannual California Species exhibition at the Oakland Museum, and some of her paintings hang in the Presidential Palace in Vilnius. About ten years ago, she generously gave the Chemistry Department some of her watercolors, which are displayed in the departmental offices in Searle. A collection of her art can be seen at [danutesart.com](http://danutesart.com). Nitecki continued to create art and host friends for many years, even as her eyesight weakened due to macular degeneration. She passed away on October 6, 2016.

*Irene Hsiao and Viresh Rawal, with the assistance of Marybeth Rice and Danute Januta*

## ALUMNI NEWS

### Jong-in Hahm

(PhD 2000) has been promoted to Full Professor of Chemistry at Georgetown University.

### Miriam A. Freedman

(PhD 2008) has been promoted to Associate Professor of Chemistry at Penn State University.

### Daniel Killelea

(Postdoctoral Fellow 2007-11) has been promoted to Associate Professor of Chemistry at Loyola University.

Congratulations to all!

Please send your news to Irene C. Hsiao, Editor, at [chemistsclub@gmail.com](mailto:chemistsclub@gmail.com).

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## From Quiz Kid to Lifelong Inventor

Alumnus George Van Dyke Tiers

George Van Dyke Tiers was born in Dalton, a suburb of Chicago, in 1927. A precocious child, Tiers garnered attention for his keen memory, appearing in cinema newsreels for his knowledge of geography by the age of three. Ten years later, Tiers was selected to compete on the *Quiz Kids*, a radio program featuring bright children of all ages who would answer tricky questions for a cash prize. Tiers demonstrated an exceptional facility with science. “I suspect my being on the show was taken into consideration by the University when they gave me an honorary scholarship,” Tiers says, noting that tuition would have been prohibitively high without the aid.

Tiers matriculated at the University of Chicago in the fall of 1942 at the age of 15 and studied in the Department of Chemistry through his PhD, which he completed under the supervision of George Wheland. Frank Westheimer, then a junior faculty member, fomented Tiers’s interest in fluorine chemistry, a pursuit that would lead him to his lifelong career as an inventor at 3M. “Professor Westheimer prepared lists of compounds to be prepared, with different techniques required to make them. I chose a list that had one fluorine compound on it, which I duly made,” he recalls. “That very same compound was the one I chose later to be a standard for fluorine NMR analysis, not because I’d made it, but because it had the properties I needed.”

Tiers’s most well known discovery is the use of tetramethylsilane as a reference standard for NMR, now used by scientists worldwide.

“The most important thing in my paper was not recommending tetramethylsilane for NMR, but the concept of putting it right into the sample instead of in a separate tube,” explains Tiers. “Internal referencing was necessary to get correct measurements. TMS is chemically unreactive, so it doesn’t alter any chemical, and it has a very strong peak, so you don’t need much of it. It was outside the range of ordinary organic compounds, because the protons attach to silicon, shifting them away from where they’re attached to carbon, nitrogen, and hydrogen. It was exciting—in an afternoon, you could determine the structure of an unknown compound, which had previously been the work of a whole PhD thesis.”

Over a career that lasted over sixty years at 3M, Tiers worked on a variety of projects, including catalysts for non-epoxy polymers that set into a hard substance, fluorescent dyes, and more. He holds over 60 patents and has published numerous papers on his discoveries. At 90, Tiers remains curious and engaged with science. “I’m trying to force myself to take the time to write up another paper,” he says. “I found a solvent that was very effective in dissolving super acids. It’s like having a pH scale for super strong acids by extending the PH scale as defined in water, which neutralizes these acids. I have created a series of chemically related materials, orthonitroamides, with a different ability to accept a hydrogen from a super acid, which I think are absolutely new.” (ICH)

# Congratulations



## AB recipients

### Winter and Spring 2017

Adrian Bustos-De La Torre  
Cameron Menezes  
Patrick O’Connor  
Samara Rusakow  
Coleman Smith  
Ran Yan  
Nicholas Zimmerman

## SB recipients

### Autumn 2016

Samuel Vexler

### Winter and Spring 2017

Lita Araysi  
Ryan Beckner  
Alexander Bologna  
Michael Burke  
Camille Corre  
Darby Dammeier  
Stephanie Diaz  
Pablo Elvira  
David Flomenbaum  
Colin Fowler  
Alan Ginzburg  
Shivraj Grewal  
John Hickernell  
Ting Hsu  
Justin Jia  
Hong Le  
Margaret Lee  
Noah Lewis  
Simona Martin  
Iliaria Merutka  
Victoria Rael  
Saicesh Rao  
Stormy Ruiz  
Mark Saddler  
Stefan Sayre  
Vishok Srikanth  
Olivia Stovicek  
Katherine Taylor  
Andrew Wang  
Maxwell Weinberg  
Kangni Xiao  
Cecilia Yu  
Ou Zhu

### Paul Calio

Christina Chan  
Natalie Chan  
Timothy Grabnic  
Wenbo Han  
Vladislav Kamysbayev  
Airi Kawamura  
Guangxu Lan  
Youjin Lee  
He Ma  
Richard Mazuski  
Andrew McNeece  
Michael Nguyen  
Kaiyuan Ni  
Curtis Peterson  
Andrew Phillips  
Huw Rees  
Benjamin Slaw  
Sara Sohail  
Ferdinand Taenzler  
Huimin To  
David Upp  
Bodhi Vani  
Laura Watkins  
Jiangbo Wei  
Lukas Whaley-Mayday  
Ryan Wood  
Tong Wu  
Rachael Youngworth  
Wen Zhang  
Xin Zheng  
Sarah Zinn

### Winter and Spring 2017

Paul Butkovich  
Jonathan Keim  
Margaret Lee  
Andrew Ng  
Zhi Wang

### Summer 2017

Ian Bencomo  
Samantha Duarte  
Vishnu Nair

## PhD recipients

### Autumn 2016

Jason Karpus  
James Kurley  
Di Liu  
Qian Liu  
Wai-Yip Lo  
Donglin Zhao

### Winter and Spring 2017

Jonathan Adams  
Zhiyou Deng  
Kenneth Ellis-Guardiola  
Igor Fedin  
Zhiliang Gong  
John Jumper  
Grant Langlois  
Edward Malachosky  
Frank Olechnowicz  
Shabana Shaik  
Chintan Sumaria  
Jacob Wagner  
Lili Wang  
Benjamin Zalisko  
Feng Zhai

### Summer 2017

Mary Andorfer  
Romit Chakraborty  
Patrick Figliozzi  
Charles Forgy  
Zhongxing Huang  
Zekai Lin  
Preston Scrape  
Jeremy Tempkin  
Andrew Valentine  
Boxuan Zhao

## Student Honors

**Barnard Memorial Fellowship**  
Rebecca Thompson

**Chenicek Graduate Fellowship**  
Jiangbo Wei

**Closs Teaching Award**  
Charles Cole  
Alex Rago

**Cross Prize**  
Huw Rees

**Gilbert Memorial Prize**  
Jianchun Wang

**Knock Prize**  
Stephanie Diaz (Chemistry)  
Margaret Lee (Chemistry)  
Anna Le (Biological Chemistry)  
Saicesh Rao (Biological Chemistry)  
Mark Saddler (Biological Chemistry)

**Knock Scholarship**  
Vishwas Srivastava

**Nachtrieb Memorial Award**  
Tim Csernica

**Norton Prize**  
Yuanwen Jiang  
Boxuan Zhao

**NSF Fellowship**  
Margaret Kelty  
Richard Mazuski  
Michael Nguyen

**Olsbansky Memorial Fellowship**  
Huw Rees

**Pedrozzi Foundation Scholarship**  
Emmanuel Valenton

**Sellei-Beretvas Fellowship**  
Kelliann Kochler

**Shiu Department Service Award**  
Sara Massey  
Daniel Micheroni  
Rebecca Thompson

**Sugarman Teaching Award**  
Jerald Hertzog  
Margaret Kelty  
Malte Lange  
Alison McMillan  
Yang Song

**Swift Fellowship**  
Xianghang Shangguan

**Viol Fellowship**  
Yan Xu

**Windt Memorial Fellowship**  
Julia Zinkus

**Yang Cao-Lan-Xian Best Thesis Award**  
Lili Wang (Physical)  
Qian Liu (Organic/Inorganic)

**Otto & Valerie Windt Memorial Graduate Fellowship:** Julia Zinkus

# *the chemists club*

Autumn 2017

*Dear friends,*

Welcome to the Autumn issue of the *Chemists Club*! While many of you may follow the Department's research breakthroughs and publications through this newsletter or on our website or social media, you will be pleased to know that disinterested parties have also taken notice of our successes—including, most recently, ShanghaiRanking's Global Ranking of Academic Subjects 2017, which declared the University of Chicago's chemistry program #10 worldwide (#6 in the US). Our dramatic rise among our peers this year reflects the excellent research contributions by our faculty, students, and postdocs, and you, our alumni. Hearty congratulations to all!

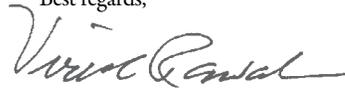
We would like to thank those who attended the Alumni Reception in June. This year, we celebrated our distinguished former faculty Willard Libby, whose radiocarbon dating experiment was recognized by the ACS Citation for Chemical Breakthrough Award. Libby's work was also selected for recognition last year by a different part of the ACS, the National Historic Chemical Landmarks Program. This will be the third Chemical Breakthrough Citations for our department, the other two being awarded for the seminal works of Frank Westheimer and Stanley Miller, in 2006 and 2009, respectively. We also honored alumnus George Van Dyke Tiers, who returned to our campus 75 years after he first arrived as an undergraduate. George has had an illustrious research career at 3M, making foundational contributions such as the identification of tetramethylsilane as the internal reference for NMR spectroscopy. In recognition of this and his longstanding support of the department, we are proud to name the NMR facility in Searle after him.

We also feature the pioneering work of Jiwoong Park, who joined our faculty last year after a decade at Cornell. Park works on atomically thin integrated circuits and collaborates across the University—most notably with Dmitri Talapin, a materials innovator whose journey from fundamental research to the practical development of a new technique for photolithography is also covered in this issue. Interdisciplinary work has long been a hallmark of chemistry at the University of Chicago, as detailed in the interview with much admired Professor Emeritus Stuart Rice.

Finally, we remember bioorganic chemist and award-winning artist Danute Nitecki (PhD 1961), who passed away last year. The Department is establishing two graduate fellowships in her name to be awarded annually to female graduate students in organic chemistry or chemical biology.

We send our warmest wishes for the new season.

Best regards,



Viresh Rawal  
Professor and Chair