Yuri Lvov: Nanotechnology, It’s the Little Things that Matter – Bonus Episode

Dave: Hello, everyone! I'm Dave Norris, Chief Research and Innovation Officer at Louisiana Tech University, and this is Beyond 1894, the Louisiana Tech University podcast.

Dave: Nanotechnology is a term long identified with scientific research at Louisiana Tech, especially since the creation of the Institute for Micromanufacturing in the 1990s. We also created the nation's first Nanoscience Bachelor's program about a little over 10 years ago. In 2012, Tech was ranked among the top universities in the nation and the commercialization of micro and nanotechnologies. Nanoscience, from which nanotechnology emerges, is the study of matter on an incredibly small scale. For the non-scientists out there, in our English Standard measurements, one yard is about three feet, which equals about one meter in the metric system. Nanoscience looks at things in nanometers and a nanometer about a billionth of a meter. The nanoscale is so tiny that a sheet of paper is about 100,000 nanometers thick.

Dave: The National Nanotechnology Initiative of the US government started in 2000, and sort of set the pace for nanotech innovation worldwide. That initiative includes numerous federal agencies, such as the National Institutes of Health, National Science Foundation, Department of Energy, Department of Defense. Among other goals, this initiative is designed to advance a world-class nanotech R&D program and foster innovations in nanotechnology for commercial and public benefit. Nanotechnology is already bringing about a wave of innovation in engineering and technology, and the possibilities for this science seem to be endless.

Dave: The global market for nanotechnology is about a trillion dollars, of which about 800 billion of that is in the United States. And these applications range from impacts on Environmental Quality, alternative or traditional energy production and storage, detection and treatment of cancer and other diseases, surgical procedures, the way we make and design electronics, the way we develop materials for all wide range of things and the list goes on and on.

Dave: So, in the studio with me today is Dr. Yuri Lvov of the Tolbert Pipes Eminent Endowed Chair in Micro and Nanosystems at the Institute for Micromanufacturing here at Louisiana Tech. As a chemist, Dr. Lvov has been one of the most influential nanoscience researchers in the world over the past 25 years. He was awarded the Humboldt Scholar Fellowship in the early 90s to conduct his work at the Mainz University Institute of Physical Chemistry in Germany. He was selected for the Humboldt Research Award in 2014, an award reserved for globally renowned scientists and scholars. He's worked at the Max Planck Institute in Germany, the Japanese National Institute of material science in the US Naval Research Laboratory. He's a member of the National Academy of inventors. And in 2008, Dr. Lvov was selected as the Small Times Magazine Innovator of the Year. The Small Times Magazine is a world-leading source of news and information about the commercialization and the commercial applications of nano micro nanotechnology. And they selected him as their Innovator of the Year not just for his scientific research, but for his impact on the commercial development of micro and nano technologies.

Dave: Yuri thank you for being here this morning and welcome.

Yuri: Okay, thank you very much that you invited me, and I would be happy to discuss what I'm doing my last 30-40 years. Yes, I am professor of Physics, Chemistry, and as well, I'm professor of nanotechnology.

Dave: So, you published an important paper in 1997, I believe. It's a date where you first laid out this nanoscience concept of layer by layer self-assembly. And that paper was recently, if I'm correct, in 2018, selected as one of the best scientific papers of the last 100 years to be published in the Langmuir journal, which is a journal named after the 1932 Nobel Prize winner in chemistry Irving Langmuir. Tell us about that paper. Why was it important? How has it affected your career?

Yuri: Okay, I will answer you in complicated way. First of all, I have to mention that Langmuir was the first Nobel Prize winner, the first American Nobel Prize winner. So special. It was 1933. First American Nobel Prize winner. And since then, American scientists so well developed now ahead of all the world Nobel Prize winners about of 200.

Dave: Wow.

Yuri: Of course, it's very high award. Hardly, like, we can get it. But we are getting quite good recognition of our research. About this paper, again, I will answer in complicated way. So in 91, I was mature scientist. I was 38. I was young professor in Russia, in Moscow. I thought life is done. I'm Professor. I'll be enjoying life other years.

Dave: You were gonna live forever, haha.

Yuri: Suddenly, country collapsed. All scientists immediately were fired by this idiot President Eltsin. No salary for scientists, no salary for university professors. He told, we don't need them, it's too much scientists. Okay, so this moment I was quite well known. And I was invited to Mainz University and got special Humboldt fellowship in Germany. It was my first high salary in western currency. It was about maybe $4,000 per month.

Dave: And it might be a good time to leave Russia.

Yuri: Yes.

Dave: Hahaha.

Yuri: And then, I came to my friend--very famous, maybe number one German physical chemist, Helmuth Moehwald. We were talking, and I remember he told, “Yuri, it's unique chance for you to start something new, absolutely new. Forget everything what you did. You are 38. Try to do something new, like graduate student. And then, we together invented this method of materials self-assembly. What means of our self-assembly? Self-assembly: when you give nature a way to create things for you.

Dave: So you don't, you don't grab a hold of these things and move them around. You give them the conditions where they can assemble themselves.

Yuri: And after we invented it, which I will describe in two words this method: so, American *New Scientist* journal writes that this like molecular epitaxy for "poor people". But you know Germany was rich. But they did this. You remember from high school that different electric charges attracted. Imagine that you have positive….

Dave: Opposites attract.

Yuri: Positive attracted to negative. And so if you have something, let's say negative glass, and you dip it in solution with positive molecule, then positive attract to negative, then next layer - again negative molecules attract, and so on. Then you will have layer-by-layer adsorption. Because plus absorb minus, minus absorb plus, and you will have precisely build up positive / negative molecules layer of any designer complex of molecules.

Dave: You're right, that did sound complicated, haha. Now, when you're working at the nanoscale, you can't pick things up and grab them with tools, you have to be able to create conditions where they can move around and assemble themselves. So, this was revolutionary.

Yuri: Yes, you rely on self-assembly. Exactly, as you told. You create conditions when they connect one to another, through some special relations.

Dave: So, this was a brilliant idea and really impacted the field. But I've heard you say more than once, "nothing comes from nothing." And what you mean is what?

Yuri: Nothing comes from nothing. It was mixture of men who was older than me, I was young. And we have based our experience on the work of Ervin Langmuir. So it was development of Langmuir work. Why it was published in the Langmuir journal? Yes, nothing is coming from nothing. I'm quite a known scientist. In most cases, our new discoveries arrived when people meet and exchange ideas.

Dave: The open exchange of ideas is critical to the advancement of science.

Yuri: Yes, but you have to be at the level. Well, high-level people, smart people are ready to talk to you to recognize you equal and fairly exchange with your ideas. Nobody will exchange ideas with someone whom he thinks is stupid.

Dave: Hahaha. Well, I appreciate you exchanging ideas with me. Now, earlier in this segment, I mentioned some of the potential application areas, broad areas of nanotechnology, and the way it can impact the way we live. And the work that you have done has been foundational in helping realize and develop some of the potential of micro and nano technologies. And the applications are broad. So, you've done work with applications and targeted drug delivery, enhancing, I guess I would say, construction or fabrication materials to make them fire resistant, mold resistant, antimicrobial, even self-healing materials, strengthening enhancement of recycled fibers for reuse, smart nano containers, let's call them. So, tell us about some of the most interesting applications that you've had in your work or that you see in nanotech.

Yuri: So, we can create very thin organized films. So, we can create films where molecules will be placed exactly as you design them: one molecule, second molecule, third molecule, and so on. So, first, we made smart surfaces, surfaces which can protect against corrosion, or which can prevent burning of plastic. For example, coated resists surfaces, which makes them biocompatible. Surprisingly, the most grants, and most research money (and you cannot do research without money), brought our technology of encapsulation of drugs. And when people discover drugs, it's only half of way to treat people. Then, you have to deliver this drug to body. And many, for example, anti-cancer drugs are very efficient but not water soluble. So, there is no way to deliver it to body through injection. For example, soluble in acetone drugs --you cannot inject acetone. And then, we suggested, and we had two big grants from NIH (National Institute of Health), and first our big grant from NSF (National Science Foundation), and when big, I mean 1, 2, 3 millions--dollars. And it was drug encapsulation, another tiny capsule. When we make, we take drug, which is very efficient. There are about 50 very efficient anti-cancer drug, which there is no way to deliver to the body because they're not soluble in water. Then, we crush it into tiny, tiny particles about 100 nanometers.

Dave: So, then it’s soluble?

Yuri: No, no, no.

Dave: Still not yet?

Yuri: So, then we coat them with polymer, which are soluble and they make this particle dispersible in water, soluble in water, and this particle is about 100 nanometer. And just to remind you, that 100 nanometers at 0.1 micrometer, 10 times less than micrometer, and our hair cross section about 50 micrometers. So, it's about 500 times smaller than the cross section of hair. Then this otherwise insoluble anticancer drug is becoming soluble and we can inject them into the body.

Dave: So you use your nanoscience concepts to, number one, make a cancer job more applicable in the body, even applicable where it wouldn't have been in the first place. And then also you've applied techniques to these drugs where you can control the time of release. So in other words, I don't just put that cancer drug into today...

Yuri: Not two to three hours, but let's say it's 40 - 50 hours.

Dave: So it can diffuse over time.

Yuri: Other application, when we had about half million $ contract with Baxter Corporation on normal delivery of insulin. Where we created insulin capsules. In our method we made small capsules and you can spray it into nose. So this formulation was actually commercialized and you can buy this product called "Promax" product, insulin formulation for nasal spray.

Dave: So your work, and nanoscience in general, has been really impactful in trying to improve the way we deliver drugs in the body.

Yuri: Yes.

Dave: So, we're not changing the drug, you're changing the way that they interact in the body.

Yuri: Yes, we are not biochemists who discover drugs. We are different. We take already known drug and formulate for more efficient delivery to the body.

Dave: So let's back up a little bit or shift gears. So you grew up in Slavgorod, Russia?

Yuri: Yes

Dave: In Siberia, in the Soviet Union, you were born in a Siberian Soviet labor camp. And at that time, your father, for lack of a better term, was a poop mover in the camp. He moved human waste from one place to place. Now, just help me understand how you go from being the son of a poop mover in a Siberian labor camp to Moscow University and then eventually somehow to the Max Planck Institute in Germany?

Yuri: You know that Russian history is tragic. As well as American, we had a big civil war, and then this civil war. My family was very rich and noble. And they lost the civil war to communists. They lost the war, but their estate was in Lithuania, which was not included in new Russia (Soviet Union). In 1941, before the Second World War, Soviet Russia occupied Lithuania and was in pact with Hitler. And immediately all Russians was arrested. Men were shot very soon (as my grandfather), and all families were sent to Siberia. I was born in Siberia. My father was 13 years old boy, his mother and others went to Siberia, and it was very difficult time. First three years till 1944, they were living in camp. But then, it was not a camp. It was like exile. So my father had to sign in local KGB office every day that he's here, and my grandma too. So it was, but I was born there. It was a restricted visiting outside. We were not allowed to go outside Slavgorod. It was small city in Siberia, but my remembers are the best. Because I was born there. When you born somewhere you like this? Yes. First of all very, very good climate. Much better than in Moscow.

Dave: Not what people think of Siberia.

Yuri: Summer. Summer we boys used only shorts, no shoes, nothing. Because summer from first June to end August, about 90-100 Fahrenheit. Then very short, very short Fall, snow in October, and snow is till April. And the winter is very cold.

Dave: It’s kind of in Southern Siberia.

Yuri: Maybe minus 20-30 degree. But very sunny, very bright everything shining.

Dave: I wonder if your dad remembers it the same way.

Yuri: Nah, nah, of course they…. And this give me kind of potential. And people were very free. It's paradox. It was Siberia. 100 % population are in exile. They're all in Siberia were exile.

Dave: Everyone's exiled.

Yuri: Everyone is in exile. So people were free with whatever, but it was not so bad place. So it was like a compressed spring union with this suppression of freedom. And when Stalin was dead, and then in 1956 it was announced freedom. It was huge enthusiasm among people. People think and until 1956 it wasn't allowed for exile people to learn. It wasn't allowed to go to high school. And then it was like spring opened and everyone started to work hard. My father got higher education at University. I was baby. I didn't remember. But it was huge suppression, but I was burn in the moment when this suppression was released.

Dave: And he found his way back to the academy and did his PhD.

Yuri: Yes. The only problem is that when he first entered the university, he was not allowed to study any engineering or science method for people who were in exile. So it's only what he was allowed to the study – Russian language. So he became a professor of Russian language.

Dave: But you had the opportunity to study science and to take advantage.

Yuri: Yes! And still, when I was at school, then we've moved from Siberia, first to Ural and then to Moscow. When my father was growing, and I was growing too.

Dave: And you started with physics, right?

Yuri: Yes, it was. It was big. I was in high school, it mid-60s. It was huge enthusiasm about science in Russia and in America, too. And it was time when the heroes were the scientists. Physicists.

Dave: You wanted to be a hero?

Yuri: No, it was like, when I was a kid, I've heard many stories about our family, about….

Dave: ...Emulate this…

Yuri: ... let's say its glory, and it was the only way to rebound family glory.

Dave: Right.

Yuri: I say I wasn't, I never was said directly became proud of our family. No, but there were so many stories about famous history of our…. For example, one of my grand grandfathers was an author of Russian hymn ("God save the king…").

Dave: Out of the Russian, like the national hymn?

Yuri: Yes, and of course, not Soviet Union,

Dave: Right.

Yuri: So this stories were maybe under my brain cover, but then they grow.

Dave: So you make your way to Moscow with a family. You go to Germany You...

Yuri: No, first I was admitted to number one Russian Moscow State University.

Dave: Right.

Yuri: It's approximate like in the US to be admitted to Harvard.

Dave: You get to Germany. You get to Japan. You create this connection with the US Naval Research Lab. Your son goes to Princeton. Your wife makes you find a way to get closer to him. Long story short, you eventually became a US citizen. And I have heard you say that you think this country is a great place for people who work hard to be successful. So why did you become a US citizen? And what does that mean to you?

Yuri: No, I think I could compare socialist Russia. I could compare German system, Japan system where I lived for years, and they could compare US. I think even we all have something to criticize. On my opinion, US is the most well for usual, hardworking people system in the world. Of course, we have some minuses, but still US allows for good professional, working hard to develop your professionalism and life at very good level. So it, let's say American style of life or I business relation correspond very well to my character. So, I think America is for strong people. I often come to discussing this with my German friends, which thinks the German system is better. They thought it's more humanistic. Yes, it's maybe more humanistic for people who are not work hard. But it's less fair to hardworking people. And America rewards, first of all, hardworking people, which I like, and which I appreciate.

Dave: And you reward the hard working students in your lab, right?

Yuri: Different. The problem is to find a proper place for everyone. There are different people, maybe. I have graduated about 25 PhD students with degree in engineering, maybe five-six from them were very brilliant, five- six, weak, and about 10 medium, probably…

Dave: We won't name any names, but...

Yuri: Everybody that you have,...

Dave: Everyone can speculate...

Yuri: Three, four, five students. So you have to find proper place for everyone. So that leaders could help other it's like, group...team. So you have to find proper place for everyone.

Dave: You know, that's a critical part of a research scientist's life that people don't think a lot of is the work involved in recruiting and organizing and managing a team of undergraduate and mostly graduate students or postdoc researchers under your wing. Bringing them along in their career. Getting the work done that you need to get done. Finding the right things for them to do based on their different skill sets, capacity, and interest and doing that year after year over time.

Yuri: Yes. To make them interested to produce things, and graduate school it's not just learning. It is to really produce something needed for people which will give you in return let's say publications, citations, and first of all grants and contracts. And we've had many industrial contracts, grants from the National Science Foundation and other foundations.

Dave: So, nanotech has this, you know, sort of "world of promise" associated with it and potential and a lot of that's already being realized. But for years, there's also been a lot of concerns that people have, you know, what these nanoscale organisms or machines might be harmful to humans or to the environment, maybe toxic nanoparticles. Should we be worried about nanotechnology?

Yuri: Well, first of all, my definition of nanotechnology: it's nothing magic, none of this. You know that in 1970s, it was micro technology like micro manufacturing technology in America, when every machine, every device was built with precision at least one micrometer. So it means engineers were trained to work with such precision, students were trained to work with such precision, all machines were produced to work with such precision. Nanotechnologies just decrease this scale of precision of industry 10 times better. So 100 nanometer it's 0.1 micrometer. So nanotechnology, in broad sense means that all our industry has to work this precision, i.e. 10 times better than micro. We have to produce machines which are working in such precision of nanometers. We have to train students to work 10 times better than micrometer and then luckily when we scaled down our scale precision to actually improve it. We found that details which we can make are really in dimension of fraction of biological cells, organelles, or virus. An ideal nanomachine, not always useful. So many viruses and bacteriophages are nanomachines. For example, this flu virus is 100 nanometers sphere. So, ideal nanomachine is virus. It's so simple.

Dave: If we can make it do what we want it to do.

Yuri: It's so, we can make many viruses very useful. There are very efficient anticancer treatment with special class of viruses, called bacteria phages. Consider that they can replace antibiotics to treat diseases. It was discovered in America to treat different disease to kill bacteria with bacteriophage viruses. Because bacteria is about 100 times larger than virus. The virus may be good bullet to kill bacteria. So there are unpleasant viruses like now Coronavirus, but we can make viruses, our friends, working for us and many sciences are done in this direction.

Dave: Now, our ability to manipulate and control things at the nanoscale is what will determine how well we can control a virus as a nanomachine.

Yuri: Absolutely, yes, there are concerns that nanoparticles may be harmful for the environment, but it's still at a very, very early stage. Still, we don't produce much nanoparticles. Still, if you try to buy a particle you can buy only grams which is not the essential danger.

Dave: But you've been building up work working specifically with a nanomaterial that is biocompatible or by biodegradable. It's eco-friendly, let's call it.

Yuri: And this hour, you know in career of any persons relay on more than one engine. The first was invented in Germany: layer by layer self-assembly and second engine which I invented Louisiana Tech 20 years ago (I'm a long time already here) is clay nanotubes.

Dave: Clay nanotubes.

Yuri: It's big advantage, that this is natural. So clay exist around us. Koaolin is one of the most common clay, which you see as a dirt in streets. And in some places, clay rolls to the tubes and this tubes - tiny, tiny halloysite tubes, and they can be excavated in millions tones and they are natural. So, they're not harmful. For example, carbon nanotube may be harmful.

Dave: One of the one of the nanomaterials that we use or devices is actually Carbon Nanotubes? Yes, and those have some toxic qualities to them and you have begun working with a naturally occurring nanotube clay.

Yuri: And I'm very jealous to carbon nanotubes. Well, first of all, there was Nobel Prize for it. But you know till now there is no even one major application of carbon nanotubes. There are small applications, while it's estimated that over $40 billion spent for development of carbon nanotube. So that is something to be jealous. So our knowledge of clay nanotube, at least 1000 times cheaper, available million ton, and it's natural product. The only disadvantage of our nanotubes is that they are not conductive. So they cannot be used in electronics, but they can be used for example for drug encapsulation, for bio tissue, for many, many...

Dave: Many, many things that carbon nanotubes can't be used for.

Yuri: Besides, in any activity, it's important to be leader. So, Louisiana Tech team working with me, is a world leader in clay nanotubes, - this hollow inside clay nanotube. It gives us many advantages. For example, we more or less control this area of research in the world. So people who want to research in clay nanotubes often approach us asking for help, like recently (you will be surprised) - L'Oreal cosmetic corporation. Company, often are trying to develop technology on clay nanotubes.

Dave: So you have clearly demonstrated in your career and your work and helped enable the broad an immense range of possibilities and applications for nanoscience and nanotechnology to impact society and human human activity. So thank you for all that work. Thank you for the time. Thank you for being here this morning. It's been great to have you, Dr. Yuri Lvov from Louisiana Tech University. Thank you.

Yuri: Thank you very much.

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