Episode 121: Ludovico Cademartiri

# KL: Katie Linder

# LC: Ludovico Cademartiri

# KL: You’re listening to “Research in Action”: episode one hundred and twenty-one.

# [*intro music*]

# Segment 1:

# KL: Welcome to “Research in Action,” a weekly podcast about topics and issues related to research in higher education featuring experts across a range of disciplines. I’m your host, Dr. Katie Linder, research director at Oregon State University Ecampus, a national leader in online education. Along with every episode, we post show notes with links to resources mentioned in the episode, a full transcript, and an instructor guide for incorporating the episode into your courses. Visit our website at ecampus.oregonstate.edu/podcast to find all of these resources.

On today’s episode, I am joined by Dr. Ludovico Cademartiri who obtained a Lauria degree in material science from the University of Parma in 2002, and a PhD in chemistry from the University of Toronto in 2008 with Jeffrey Rosen. He was an NSERC postdoctoral fellow in the group of George Whitesides at Harvard University. His work spans materials chemistry, physical chemistry, molecular electronics, flame manipulation, plasma processing, polymers, and environments by design. And has been recognized by national and international awards. Most recently the Beckman Young Investigator award, and the Plant Science Institute Faculty Fellow award. He has been at Iowa State since 2012.

Thanks so much for joining me on the show today, Ludovico.

**LC:** Very good to be here, and to talk to you.

**KL:** Ok, so I'm excited to dive into some of your research on plants. And in particular, I'm curious, what led you to research different plant habitats?

**LC:** Yeah, so we we're interested in understanding how plants respond to the, to the environment and to other organisms. So this is a very complex type of problem, because it involves first of all living organisms, which are temperamental, and very responsive, and can behave very differently. And it involves a very large number of environmental variables, which could be the temperature, the humidity, the light intensity, duration of the day. All these things affect plant growth.

But the, what we are especially interested, beside this physical characteristics of the environment, like as I said temperature, humidity, and so forth, is the potential for biological interactions. So interactions between the plants and other organisms surrounding it, which could be microorganisms, especially in the root system, and not only in the root system. As well as other plants. So there is the potential for plants to interact both above ground and below ground with other plants. And I think that that's where the questions become rapidly, extremely fascinating, in terms of what plants might, what kind of, what could be the hidden life for plants in a sense.

And the reason why I think it might be hard for listeners to quite understand why an engineer might be involved in working with plants it's certainly very unusual, certainly for a material scientist to be involved with the work on plants. So my, I, first of all I come from a very interdisciplinary background in terms of my early, early research during my PhD in my postdoc. So I'm used to think very laterally about problems. And the realization came pretty early that there are opportunities, that are, there are possibilities associated with the know-how, that we can bring to the problem.

And the know-how material scientists is largely that we can build anything. We can make anything. That's how I would summarize the material science toolbox to, to the audience. And so the ability to be able to create anything, gives us the possibility to resolve I think problems that are very tricky in in plant science, and agronomy. Yeah, so, so that's where I think we can make a really big difference.

**KL:** Okay, so I'm curious about what you're hoping to learn about plant habitats and ecosystems. You mentioned kind of some fascinating questions. What are the things you're really, you know if you could solve it tomorrow at the snap of your fingers, what are you looking to figure out here?

**LC:** Well, it's hard to pick one because there are so many important questions. And there are there are things that could be very interesting to know. And there are things that could be very important to know. And those things are not necessarily the same.

**KL:** Right, right.

**LC:** So the very interesting ones would be to understand to what extent plants exchange information with each other through the root system. What that information is, what it allows them to know about their environment. So the question would be what kind of information can plants collect from their environment by basically communicating with each other through of course chemical molecules. So that would be very fascinating because it would change our view of the plant communities, as just a collection of individuals, to actually a collect, a community an actual community of interacting individuals.

And from a, from an important point of view this could be extremely important. But certainly what is very important is the ability, it would be the ability to predict what a plant how a plant will grow as a function of its environment. This would be absolutely transformational in terms of, for agronomy and for breeding of new crops. Is if we could say, if we would be able to say on the basis of certain genotype, of a certain DNA of our plan, that we've developed or that we bred. That this plant is going to produce this many bushels of corn. This many bushels of corn per acre with this specific environment, with this specific weather pattern. That would be that would be very important. That would be very important.

**KL:** Yeah okay, so I stumbled across one of your papers or one of your projects where you were researching Legos as a potential plant habitat. And Legos are probably something that many of our listeners can connect with. They know what they are. But I'm curious, what led you to research Legos as a potential plant habitat?

**LC:** Right, so the Legos are very interesting. And while I told you before that we material scientists can make anything, and that's, that's true. Sometimes is a lot simpler and cheaper to just get it already made. This is one of the examples. So one of the challenges of making habitats for, from biological organisms is that there is a very long series of requirements that this habitants need to fulfill. And I can list you a couple so that they have to be transparent, chemically inert, they need to be cheap, they need to be very precisely made, and the list goes on and on and on. And so what might look like a very simple problem, like how do you create a habitat for a plant? Once you start adding all these requirements becomes actually quite rapidly complicated in your art, as your options very rapidly shrank.

So what we found is that Legos, because of the fact the transparent Legos, because they're made of polycarbonate they are actually an ideal building block to create habitats for living organisms. Because they can be out of clave so that means that they can be sterilized. And they are beautifully transparent. They’re very precisely made. And their modularity allows you to create any shape of habitat that you want. While and they’re cheap, they could be cheaper. I wish they could be cheaper. But they're still they still can be reused dozens of times if not hundreds of times without degradation.

So it's really it ended up resolving a number of issues, a number of challenges at the same time. And so this is why it was kind of combining a good solution without, with actually playful solutions so that that was a good one.

**KL:** So I'm curious if this research intersects with your lab also that has an interest in unusual structures. Do you consider the Lego an unusual structure, or is it just kind of fulfilling the need of these criteria that you're looking for?

**LC:** Well, structure is a big word that depends a lot on the scale that you're talking about.

**KL:** Right.

**LC:** So we are interested in structure on many fronts. But there is an interest, we have interested in structures, for example, in terms of the root structure of plants. We're interested in the structure of materials. And that in that case becomes an atomic structure, as well as everything in between pretty much in terms of length scales. So structure is a beautiful, our beautiful problem, especially when you start thinking about how structures can self-assemble and put themselves together by themselves. So that that is an interesting topic, yeah.

**KL:** Alright, well I think we're going to dig in a little bit deeper. We're going to take a brief break. When we come back we'll talk a little bit more about using plasmas for nano structure processing. Back in a moment.

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# Segment 2:

**KL:** Ludovico I know a big part of your work is using plasmas for nanostructure processing. And I want to break this down in an attempt for me to understand it better, but also for our listeners as well. Let's start with just what is plasma, because I think that the way a lot of people think of it as probably tied to blood. But I'm not sure that's what you're talking about here. So how are you defining it and out and using it in that work?

**LC:** Yeah we're not working with blood, at least yet. So the plasma that I'm talking about is what is considered the fourth state of matter. So it is effectively a kind of gas. It's, its gaseous state of matter in which you have charged species. That could be electrons, ions that are floating around and are being accelerated by an external electric field. So think of it as having usually a relatively small amount of these very highly energetic particles in your gas that are being accelerated by an external electric field. Then whenever these very fast moving objects hit no charge, uncharged gas molecule they can split it apart and creating more charge molecules, more charge species. And those can get then accelerated. And so you have then what is a plasma.

So any of you that, as common examples of plasmas, are electric arcs. An electric arc is a plasma. A flame actually turns out to be a plasma. It has charged species in a flame. Other examples, part of corona discharges. So corona discharges. Some people might be familiar to them. Some familiar with them in terms of they're called St. Elmo’s fires. In, they've been observed in ships, in big storms, has basically these glowing clouds that occur close to metal spikes. When that occurs because we're breaking apart the air. And so you're forming a corona, and that's called that's plasma.

**KL:** So it's a very, very diverse type of range of states of matter. But it's essentially an electrified gas. Okay so you're then using this for a nanostructure processing. So let's break it down even further. What are some of the, like talk to us about nanostructures. What do you mean by that? What are some examples?

**LC:** Right, so, the, what we're trying to do is to basically develop a new way to make materials with a very highly controlled structure. And instead of, instead of creating the material in the more traditional way which would be. I can give you one example which would be you start from for example molten metal and then you cool it and that would create just a sheet of metal.

In our case what we try to do is to basically build the material from the bottom up. So we create very tiny nano crystals of the material that we want. And those are surrounded by an organic shell, organic meaning molecular shell, that makes them dispersive on in liquids. So these things they can behave like small molecules. And then we can deposit these little spheres of an inorganic matter, on on a substrate or material. But then the issue in order to convert them to new materials is real solid statement use, is how do we remove that organic layer of molecules on top of the particles?

And this is where plasma comes in. Plasma in, allows us to remove those, those molecules that would separate these crystals. And so allows us to essentially consolidate the material, and to make it become a solid instead of just individual spheres, colloidal spheres on a substrate. And so this allows us essentially to think of it as, as this colloid says bricks and mortar. So the shells on the on the bricks are the mortar. And we assemble all these bricks together, with all the mortar surrounding them. But eventually for properties we want to be able to remove the mortar in between the create essentially a unique single piece. And that's where plasma is exceptionally capable because it can penetrate the material and remove all this quote-unquote mortar within, and consolidated material. And so that allows us to really design the structure from the bottom up, just like you can design a building from the individual bricks.

**KL:** Okay, so I think I'm following here. What are some of the practical applications of doing this, you know of removing that with the plasma so that you have this more solid structure. What is kind of the outcomes of this that we might see in kind of day to day life?

**LC:** Right so it's. There are some practical applications and there are some scientific applications. The practical applications, has to do with in general performance over, it can be optical performance electrical performance. And that has to do with the fact that the property of materials does not depend only on the way the atoms are arranged with respect to each other. And their chemical nature so whether it's aluminum or copper or oxygen. It has to do also with how the material is structured at a larger scale. So we're talking about nanometers, micrometers, and so forth.

So think of it in this term: it's like as if the strength of the building that we are talking about with the bricks and mortar. You know that analogy. It's as if the strength of the building, its ability to resist earthquake would depend on the size of the bricks that you're using. Okay, so in the same way the conductivity of a material would depend essentially on the size of the crystals within it. And the mechanical properties would depend on the size of the crystals within it. So the size of essentially this bricks that compose it. So this is what is calling in in our jargon microstructure. So microstructure has tremendous influence on the properties of materials. So the ability to control it very precisely is essential for creating new and optimal materials.

**KL:** Okay, so I'm curious what are the tools or methods that you're using to do this work. You know like what if someone was to imagine you actually doing this you know in a lab, what does that look like?

**LC:** It's, it's actually no we don't use anything that is particularly fancy. So the these particles that we make these colloids that we made for example are made in solution like in a flask like a good old chemical reaction. It's a little usually a little bit high temperatures, but not necessarily. And we just inject one thing into another. And things precipitate. And then we wash them, and then we disperse them. So it's nothing particularly science fictiony. Or it's not a very Hollywood vision of science.

Then we use plasma, as plasmas are also an extremely easy thing to generate. You just basically need a vacuum chamber. And then sometimes not even vacuum you can do it in a microwave at home. The lack of chamber in an electric field, and you can have this beautiful glowing gas in there. And so we'd like to use very simple tools because they're cheap. They're harder to break. And if something breaks you typically know how to fix it. And that has a lot of advantages over very complicated pieces of equipment, which are often, more often than not at work so. And also it stimulates the creativity in the sense that if you need to find a simple solution it makes you a little bit less it makes you a little bit more demanding on yourself. And so that's a good thing.

**KL:** Well I'm definitely an advocate for a simple tool. So that's exciting to hear that that's what you're using. We're going to take another brief break. When we come back we'll hear a little bit more from Ludovico. Back in a moment.

[*music plays*]

# Segment 3:

**KL:** Ludovico I'm always really interested in people's origin stories, and particularly when it comes to science there are so many different skills and abilities that you're bringing together to where you are now. So I would love to hear over the course of your career what are some of the building blocks of the skills and abilities that have really led you to doing the work that you're currently doing. And I'd love to do it a little bit chronologically. So let's start with undergrad. What are some of the things that you picked up during those undergrad years that you're kind of still utilizing today?

**LC:** Well I did my undergraduate in Italy. So it's a pretty different educational system. And I did my undergraduate material science which was a strange new degree for Italy. It was really at the edge of chemistry and physics. And that was basically the reason why I picked it was that it allowed me to study both chemistry and physics. I didn't want to know only one. I think that what was essential for me from undergraduate was just competence, pretty much. Competence was essential, and we were we were grilled pretty hard back there.

And the other, another skill that I learned that was essential I think, and very valuable was the ability to explain my thoughts. And that's a skill that in Italy is developed pretty early on in the educational system, because we go through typically most of the assessment in class starting from pretty much middle school, but certainly all the way to undergrad it is all what we call all interrogations.

**KL:** Okay.

**LC:** You're literally interrogated by the by the by the professor. So you're basically flipping roles. So that the professor becomes the student and you become the professor. And you need to answer the questions verbally at the board and so forth. And so it's not sufficient just to be able to solve problems, or but do things of that kind. You actually have to elaborate your thoughts, connect ideas with each other and find your own words to describe things. And that is a very important skill to have, because it also facilitates writing. It facilitates the crystal, the crystallization of your understanding of things. If you can speak it out, word has such a powerful influence on the way our brain is able to organize information. And so it's extremely important, yeah.

**KL:** Okay, so it sounds like an undergrad you were really solidifying the content knowledge of your fields, and also learning to do some of that kind of metacognitive work of learning how you're learning, being able to express your learning.

**LC:** Absolutely.

**KL:** When you shift it into graduate school, what were some of the kind of building blocks that we were layering on to that earlier learning experience?

**LC:** Well graduate school was a really fun time. It was the first time I left my country. And there was a lot of freedom that I was given in terms of pursuing research. I was already capable of doing research. I had probably some, a little bit of talent in sort of picking ideas, doing dabbling around in the lab doing things. So I really thrived in in in an environment that was allowing me to really go off and do things without really too much supervision. I was also privileged to be in a laboratory where the we're absolutely remarkably skilled and competent individuals that were very generous with knowledge. And that allowed me to grow extremely rapidly, as a scientist I hope.

The, what I learned very quickly, but it's something that I kind of knew already is that the it's very important in I think in during your education, especially in grad school, and beyond to truly trust your advisor. And there is a, there is a sort of our paternal/maternal relationship that must exist to some degree between the student and the advisor. And in order for that to be very fruitful there needs to be a mutual trust. And, and so in a sense you need to accommodate without I, I think it was very valuable for me to come at it with a with a notion of trying to forget everything that I thought I knew, and entrust what I what I was being given by my advisor, right? And I found that that approach is extremely valuable because it makes you really a sponge. Because there is, you do not pose any resistance to what you're getting. You take it all in, and you postpone your evaluation of that information, of that mole of knowledge that you get to a later date. That you say well I'm gonna reanalyze and put all of this together at a later date. And so I think really embracing that that kind of relationship it's very important I think for the success of not just me I think, for a lot of people that I've seen.

So that was very important it was a very productive time for me. I've learnt a lot I learned how to be productive which is very important. So the ability to work the ability, to have eight hour work where you're never still, you're always doing something, absolutely fundamental skill to have as a as an experimental scientist. And it makes it more fun, because you at the end of the day you come home and you say wow I did a lot of stuff today. And that would that's very good warning.

**KL:** Okay so after graduate school, postdoc right. What are you building on with your postdoc?

**LC:** That was yeah, that was quite an experience that was quite an experience one of the really high points of my life. So I had the privilege to work with Professor Whitesides at Harvard Universities. So it's an extremely, extreme privilege. And the choice was really about working with him, and trying to learn as much as possible from him that I could. Because I was interested already then on the work on plants. I already wanted to move in that direction plants and soil. And professor Whitesides has demonstrated in three in a million ways how to move into very complex problems from the outside. So moving in as an outsider into a new field, and how to make a contribution that is that is that is important. And so I learned I learned an enormous deal in terms of how to do research on complex systems. The importance of simplicity and about science the practice of science as a whole. And that was extremely valuable. I, you can't quantify the extent of the change. I don't think I would be quite the way I am as a scientist if I wouldn’t have gotten through that experience. So that was absolutely invaluable.

**KL:** Okay and post postdoc.

**LC:** What am I learning now? Yeah well I'm learning a lot about academia I'm learning a lot about education I'm learning and the challenges of education and how these challenges are changing so rapidly, because of the changing expectations and attitudes towards education. I'm learning a lot about the research itself. It's and how it's a very human activity. It's a very human activity with all its advantages and disadvantages. it's made by humans, interpreted by humans and it's a, it's a beautiful activity. Like the way I phrase it is usually that it's one of the most noble activities man can do is because it represents the pursuit of truth right? And it's the pursuit of something that is almost unattainable I would say. But the fact that you're pursuing it is what makes it noble. And I think that that is something that you know gets you up in the morning and gets you going.

**KL:** Well Ludovico it's been such a pleasure to talk with you today thank you so much for sharing about your work.

**LC:** Thank you very much, thank you very much bye-bye.

**KL:** Thanks also to our listeners for joining us for this week's episode of “Research in Action.” I'm Katie Linder and we'll be back next week with a new episode.

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