CERAMIC TECH CHAT

Episode 65

Title – “Cross collaborations for multifunctional electronics: Ruyan Guo”

INTRO

McDonald: “I’m Lisa McDonald, and this is Ceramic Tech Chat.

Research can be a frustrating experience when you lose sight of the end goal. But supportive mentors and colleagues can help you find the reason for your hard work, giving you the direction and motivation to continue striving toward great things.”

Guo: “Dr. Rustum Roy actually was a fierce scientist. I think in my interaction with him, he never says anything dull; he says things with flavor. I mean, he really inspired students or at least wake you up in any classroom that you were sitting with him lecturing. So, actually I think interactions with him really challenged me to balance the pure discovery with the real-world relevance, so we would not lose sight of how materials can really solve problems and actually serve people.”

McDonald: “That’s Ruyan Guo, the Robert E. Clarke Endowed Professor of Electrical and Computer Engineering at the University of Texas at San Antonio. Ruyan specializes in the study and development of multifunctional materials for electronic devices, which has opened both exciting and surprising career opportunities during her 40 years as a member of The American Ceramic Society.

In today’s episode, Ruyan will talk about her experiences doing research at both The Pennsylvania State University and UT San Antonio, describe how she helped launch an interdisciplinary graduate program at the latter institution, and share the ways in which she is giving back to the ceramics community by serving previously as a National Science Foundation program director and currently on the ACerS Board of Directors.”

(music)

SECTION 1

Guo: “I believe my pathway really started back when I was in China in the Xi’an Jiaotong University. I earned my bachelor’s and master’s in electrical engineering there. So, I was trained as an engineer, not quite a materials scientist. That’s back to late ’70s and early ’80s.

So, one lecture that I took in China, it changed my trajectory. One of the professors in China called Dr. Yao Xi. He’s actually a member of Chinese Academy of Engineering, and he is widely regarded as one of the founders of ferroelectric ceramics research in

China. I heard his lecture and actually learned about perovskites, speaking about ferroelectrics being a family of materials that has potential. So, I fell in love with how materials could control electricity.

So, Dr. Yao Xi, he just returned from Ph.D. in Penn State University, and he actually was regarded perhaps one of the very first Ph.D. recipients in the materials science field for Chinese, I think since 1949; I think that nothing happened in between. So, that was a very special opportunity that I had. So, that actually pushed me to come to U.S. and pursue my Ph.D. in solid-state science in Penn State. So, I kind of combined engineering and science training ever since 1985.

If I recall my student days, I really value the time I spent with my advisor, Dr. Eric Cross. Dr. Eric Cross actually was an absolute icon in ferroelectrics at the time, so I think he told me how to do application-driven research, and that's something important. Always asking what problem does this solve? You know, if you have a problem that need to be solved and also how can it make a real difference if we do any research. Plus, I believe in a way, we as a young researchers learn how to seek funding, how to write strong proposals, and thinking big about impact. I think that's something that is a very valuable lesson that I have.

I stayed at Penn State for almost 20 years. So, really by starting as a research associate in Materials Research Lab and eventually working my way up to be a fully tenured professor in electrical engineering. Then, my career pathway took me in 2007 to this wonderful opportunity to join UT San Antonio. There's an endowed professor position in electrical engineering. So, I've been here ever since."

McDonald: "Awesome. And so as we know, and probably some of our listeners may know, electronics are used in all types of applications. Do you have a way to maybe break down for our listeners some of the main applications that you work with and what types of devices there are and then how those devices are used in application in everyday life?"

Guo: "Absolutely. Our lab really works on a pretty wide family of devices. We build around the multifunctional ceramics. So, they are doing multiple things at the same time. Like sensors and actuators, things that can feel the pressure, feel the temperature or even magnetic fields, and so they can respond with motion or with signal. That's really the area that we really are interested in that. But, you know, application-wise, it's very connected to optics, communications, robotics, energy harvesting, you name it, yeah."

McDonald: "Ceramic materials are really good at offering these multifunctional capabilities. But of course, not every ceramic is going to be good for every application. But are there certain groups of types of ceramics that you see coming up again and again or that you use a lot for these electronic applications?"

Guo: "I think definitely the rockstar has been the perovskite family. So, perovskite is a name given to a prototype family of materials, essentially calcium titanate; it started with that one. And that forms oxygen octahedral framework with a larger site to fill in with other cations.

So, kind of a very interesting thing is a perovskite as a structure is well defined with their coordination and the bonding condition, but their symmetry can evolve as many different variable goals. So, you can go from a cubic, which we call prototype, and you can go for different symmetry like tetragonal, like orthorhombic, like rhombohedral, you name it. So, there's a different form and shape, but because of that, they allow coupling between the cations and anions; they form polarization.

So, that polarization and the direction of the polarization actually enabled a lot of this kind of directional-dependent application, for polarization control, for phase-switching materials, for memories, for all of the speakers we use, the motor we drive, using it in our cameras or our cell phones or TV sets, many, many of those kind of application examples.

So, you see the name PZT [lead zirconate titanate] coming up everywhere. You probably also see barium strontium zirconate. So, perovskite is standing out.

I personally also have as my personal favorite is that I worked with tungsten bronze. So, tungsten bronze is another family that actually is a cousin with perovskite. But that family of material actually provide a lot single crystal kind of family of capabilities that are very important for photonic applications. So, that's another one.

So, I think now we are moving further with semiconductors, materials with ferroelectric properties that actually morphed into semiconductors; that is something relatively new in our field. And so, electroceramics really cover a very wide spectrum of properties, as far as the electrical properties are concerned."

McDonald: "Well, that is just so interesting, isn't it? How with these structures, making these small different changes to like where the ions are located or like specific elements that are being used on the structure can have very large effects on the properties.

But of course, to be able to do this delicate design of the structure, we need to have manufacturing methods capable of working on such small scales. So, have you been working with some of these novel manufacturing methods in your lab? And if you have, do you have maybe an example of some of the unique capabilities they've unlocked that you weren't able to do with more traditional techniques."

Guo: "So one of the approaches, additive manufacturing, 3D printing, everybody knows about it; everybody could have it in a garage. However, the 3D printing that I think of contributing for electronic ceramics is still evolving, I don't think it's mature yet; we're still learning how to do that.

So, one of the things that we do in my lab, we are actually using nanomaterials, we are actually developing nanomaterials, so they are becoming the main component of the ink, and that ink actually can be deposited. The deposition can be several different ways. You can do inkjet printing, you can do aerosol spray deposition, and the combination of all the different technology, or direct writing. So, there are many different technologies.

In my lab, I have very fortunate with a Department of Defense support, we were able to acquire state-of-the-art equipment, combine different additive manufacturer tools in one platform. So, we'll be able to fabricate nanomaterials and in a digital resolution, dot by dot, but also integrating with different types of materials. And that is really a very high potential in a way to allow us to design what material, what device you want and then built in both conductors, insulators, semiconductors, ferroelectrics, functional materials, all into a same build. And you can form that one, that is really exciting to have that capability in doing that.

So yes, this is something would allow us to make things more compact, more green, and more efficient in energy and time, and also unique capability that was never before available. And especially I think because the digital additive manufacturing for this kind of approach, make each device can be customized and can be personalized. So, you don't have to make one mode and keep on generating everything for everybody the same. You really can target individual need application to make them. So, I think this is very powerful."

McDonald: "The two sides of this situation are so fascinating because, like you said, with all of this advanced technology, we can make things so personalized to a very specific application now, to a very specific person needing a unique thing. And yet to be able to get to that very personalized solution, we have to pull from so much vast knowledge from so many different groups. We need to know about electronics and computers and physics and chemistry, maybe even biology, so that we can come together from all this broad umbrella to come to this very personal solution for people.

And so I think it really shows that those of us who are creating these devices need to not only have maybe an appreciation or an awareness of all these others but know how to network with our friends in an interdisciplinary sense so that we can achieve this efficiency and this effectiveness."

Guo: "Absolutely. I think you just said it perfect because this is all what I tell students also. I think electronic materials and devices, they are really sit at an intersection of physics, chemistry, materials science, and even biology about electronics, you name it. So, you really can't do cutting-edge work anymore without talking across those boundaries anymore."

(music)

SECTION 2

Guo: "When I arrived at UTSA [UT San Antonio], I saw that there were strong engineering programs, but there was no dedicated graduate home for materials that pulled everyone together. That perhaps is a motivation that we have a push for creating the graduate program that is interdisciplinary and that actually attract a student from electrical engineering, mechanical engineering, chemical engineering, biomedical engineering, physics and chemistry and biochemistry. So, different background students actually come to pursue their graduate degree but targeting the problems that is really interdisciplinary, to address those kinds of questions. I think that really is a critical, important platform for anybody who is interested in electronic ceramics. So, you do have to have an interdisciplinary and expand your horizon of knowledge."

McDonald: "And it's really great getting to hear about some of the thought process that went behind this interdisciplinary engineering graduate program at UT San Antonio, which as you mentioned, you helped to establish, direct, and grow. It's been around for about a decade now, so what are some of the biggest benefits or outcomes that you've seen from this program's existence? It's quite a unique program as well."

Guo: "Yeah, it's the first one at UTSA for this kind of interdisciplinary program, but definitely it's not the first one in the nation because of Penn State and MIT, those are pioneers. I myself actually have been a product of the Penn State interdisciplinary program. But yes, any such effort is challenging on campus. It's not that easy because you do have to find a room to host you; you don't belong to any individual department, you're interdisciplinary. So, there's a lot of challenges, but I do say that is very rewarding in a sense that we have really trained quite a lot of students graduating from this program.

And you can say that important thing for me to feel that you do have students at the end of the program, they can speak every language in the room. Because you have engineers who understand chemistry, you got a physicist who can build devices. Really that's very amazing to see that one.

And so, we have seen all the collaborations bloom, and you know, that means giving faculty opportunities to collaborate as well. So, that eventually will result in higher research output and maybe also definitely graduate students landing great jobs. So, I will say this is really the important outcome for that one. I would hope that maybe by chatting with you, we can convince more administrators to put more resource into this kind of program and support more of this kind of interdisciplinary programs."

McDonald: "And I think that is just so important. You know, like you said, that these types of things don't happen in a vacuum, especially an interdisciplinary program. And that's why I'm so thankful you pointed out that you are a product yourself of this type of experience from Penn State, MIT has it, and being able to educate these students to go out and use these skills, be that in industry or establish it at other universities, similar programs, so that more students can have this interdisciplinary experience. It's just going to benefit society as a whole, and it's really great to see."

Guo: "Thank you."

McDonald "So, with all of your experience in electrical materials and devices, in addition to having all these great experiences with students at university level, you also had the exciting opportunity to serve as program director in the Electrical, Communications, and Cyber Systems Division of the National Science Foundation's Directorate for Engineering from 2019 to 2022. So, can you kind of tell us about how do you even go about getting an opportunity like that and how it was?"

Guo: "Yes, I think that I'm very proud that I have served, you know, national scale for federal government at the National Science Foundation. You know, opportunity came knocking. It's 2019, and I think NSF needs IPAs [Intergovernmental Personnel Act Assignments] that's called Rotator Program Director. So, they need IPAs, they want people who have active research portfolio who are engaged with both education and research and they can bring in new ideas and the new perspective to NSF. That's what the Rotator Program is about.

And so, I'm interested to also contribute because I was already reached to the certain stage I felt that I could enrich myself more and maybe pay back a little more. So, that's a perfect time matching for that. So, I think I have experience in electronic materials and photonics, that's the position they're looking for. So, I served from 2019, actually three-and-a-half years I was at NSF as a program director. I was involved primarily in the coordinating and managing electronic, photonic, and magnetic devices program. So, that was that was a very rewarding experience for me."

McDonald: "What do you think were some of the biggest things you learned from doing research on such a large scale? You know, at that national level versus just doing research on like the university level?"

Guo: "Well, at NSF level, at a federal level, you are not doing your own research, per se. But you are kind of adapting based on your own experience and your knowledge, you're able to help the organization to support and to stimulate and to organize nationwide research programs. I think that's the job of program director, not to grow my own research anymore. In fact, I found out at NSF the more you know, the more you need to learn.

So, I was exposed to very different programs and all different fields. So, that was really challenging and rewarding because of that. But I did from that position, I did oversaw proposals and projects spanning everything from novel photonics devices and quantum-inspired ideas and telemedicine technology.

Also, because the height of pandemic during that time, COVID, and we also actually see we are very critical to find those research very timely that it can be immediately adapted to relieve the problems caused by COVID. So, that's really a rewarding for that. A lot of teams pivot at that point because NSF encouraged them to do so to help hospitals and to help doctors and help patients in that way, so that was good.

Certainly I was involved in many programs. So perhaps also another thing is the exposure to facilitate, to help developing programs that have the international impact. That was a time when CHIPS actually initially started [CHIPS and Science Act of 2022], we were pushing for that one. So, they established an international program. Also, the program directors knock our head together, putting up a program that challenge individual PIs to go as a team and to solve larger scale problems. So, now just for one lab really you have to collaborate, which is a requirement, and solving system-level problem, not just a single device problem. So, that was a very rewarding. I believe that has made an impact to the landscape.

But anyway, I know that this is not a place to worry about, but I find after going to NSF, I still find our nation need a better support for engineering. We still need more funding."

McDonald: "We always need more funding for engineering, for science; it's always so important. It was very fortunate in some ways, I mean stressful, but also fortunate to be able to help serve in that role during something like the pandemic. It really gives you a really good perspective on the ability of scientists to adapt and to pivot and to be able to engage on short notice, to respond to the challenges as necessary. And it really in some ways can be inspiring to see, you know, how scientists and engineers are really able to step up to the plate in those types of situations and innovate to come to solutions."

(music)

BREAK

McDonald: "The American Ceramic Society's Electronics Division focuses on electronic materials and devices in both traditional interest areas as well as emerging research areas. This Division is one of six coorganizing the newly launched ACerS Spring Meeting. Learn more about this Division at www.ceramics.org/electronicsdivision."

SECTION 3

McDonald: "So, with all of this experience of you getting to realize you're at a point in your career where you can step up and start serving in some of these roles where you're not necessarily doing the research yourself but helping to direct the opportunities to enable younger, up-and-coming researchers to get to the point that you are at now. You are currently serving as one of our Board members on the Board of Directors for The American Ceramic Society. And of course, we always love to know, how is it that you first came to become a member of ACerS?"

Guo: "I actually joined the Ceramic Society as a member the first year I came to the United States. In fact, I recall I went to classroom in 1985, fall of 1985, and I was taking class offered by Dr. Robert Newnham, Bob Newnham. He actually openly in the class encouraged students to become members of Ceramic Society. And I just right away, I think made that decision that 'This is going to be my home.' So, I joined right on there.

I think I applied in fall of '85, and my membership record actually kickstarted in the beginning of 1986. So, I'm talking about 40 years this year. So, I've been with the Ceramic Society as my academic home and professional society home. I'm very, very pleased that I made that decision and it has accompanied me for all these years."

McDonald: “That is just so exciting, when we can hear from members who have really been here since their student days through now. And now you’ve really been able to feel the support and the transition yourself of how the Society supports the young researchers. Now you’re in the area that you can help inspire other people to get involved and grow through their careers.”

Guo: “Yeah, absolutely.”

McDonald: “So, I know we’ve already covered so many different things today, but I always like to ask, are there any like funny stories or maybe serendipitous experiences that have really carried with you through all of your years of doing research that could maybe inspire our younger listeners?”

Guo: “So, I think my hands-down, the surprise to me is there’s the smallest medical robot came out of my lab.”

McDonald: “Oh, that’s exciting.”

Guo: “Yeah, it was kind of unexpected. Because one of our doctoral students, now he is a professor in IIT Delhi, India, at that time he was working on the doctoral dissertation with us and also my colleague, Dr. Amar Bhalla. I’ve been teamed up with Dr. Bhalla for decades, first at Penn State and then at UTSA. I’m lucky that I have someone to push each other and to support each other in that way. So, I would say, I’m lucky to have his support, wisdom, and energy.

So, we were working on nanomaterials. So, the nanomaterials including one of the materials called a core–shell nanocomposite that included cobalt ferrite and barium titanate, so that’s a combination of the materials for that one. But this one, in fact we called it multiferroic materials. But this project that was being successful, but it took a little unexpected turn into nanorobotics. Because when we study material, we always assume the material is contained in a system; there was no motion to that material. But then we realized this little nano stuff, if you look at it under a strong field, it actually shivering around, moving around. So, that was quite interesting.

So from there onward, we pushed that idea because the next thing we know, this is becoming the tiny core shell nanocomposite entered in Guinness World Record considered as the smallest medical robot. So, I was very pleased, surprised to find that out. It’s about 120 nanometers, and so far, no one has built a robot as small as that one. And we have shown it was able to move upon the influence of a magnetic field, entering the cell membrane and potentially can penetrate and deliver a load. So, that actually could be considered nanorobots.

So, that was exciting. It’s not expected, it’s not what I have in mind. It’s a student who was creative in doing that one. But I think keep your eyes open, serendipity may knock at your door.”

McDonald: "That is why it can just be so exciting to work with so many different people. They have these ideas you never would have thought of on your own, and it opens these brand-new doors to Guinness World Records."

Guo: "Currently, so far. So, we'll see."

(music)

CONCLUSION

McDonald: "With the rising trends of electrification, renewable energy, and artificial intelligence, electronic devices are becoming more relevant than ever before. By working together in an interdisciplinary manner, we can create the multifunctional materials and technologies necessary to fulfill the ever-expanding and complicated needs of modern society.

I'm Lisa McDonald, and this is Ceramic Tech Chat."

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"Visit our website at ceramics.org for this episode's show notes and to learn more about Ruyan Guo and her research. Ceramic Tech Chat is produced by Lisa McDonald and copyrighted by The American Ceramic Society.

Until next time, I'm Lisa McDonald, and thank you for joining us."