CERAMIC TECH CHAT

Episode 03

Title – "Integrating Research for a Greener, Cleaner World: Clive Randall (E03)"

INTRO

De Guire: "Welcome! I'm Eileen De Guire, and this is Ceramic Tech Chat, the podcast of The American Ceramic Society.

Over half of people pursuing undergraduate studies in the United States are first-generation students, according to the data from the National Center for Education Statistics, which defines 'first-generation' as students whose parents did not have a bachelor's degree. And yet first-generation students are often talked about as a minority on college campuses, and they sometimes face a stereotypical expectation that they are more likely to fail in college because they lack persistence and confidence.

But the truth is many first-generation students do graduate and go on to very successful careers. And once they've found success, their back story is often overlooked, missing out on a great opportunity for them to become role models for first-generation students today.

Luckily for us, that opportunity is not going to be missed today."

Randall: "I'm a first-generation person, I didn't go to university until I was 21, even as an undergraduate. I thought they were all Einsteins. I was misinformed."

De Guire: "That is Clive Randall, director of the Materials Research Institute at The Pennsylvania State University, where he has been a professor for 32 years. Clive, an expert in the field of ferroelectrics and ceramic processing, is himself a first-generation college student. But what compelled him to pursue a university education? And how has he used his journey to help others?"

(music)

SECTION 1

De Guire: "Unlike some of our guests on this podcast, Clive did not go to university right out of high school. Instead, his inspiration to go to college came a few years later."

Randall: "I was working as a technician in an animal food staff in a place called Ipswich in Suffolk. And everyone told me that I should go to university. I didn't believe them. I had a boss that was continuously teasing me. And there was one day when I saved a process, which then made everything go out, and he took credit for it. And that night I applied to university. He did me an enormous favor."

De Guire: "Yes. And did you have any thought of a Ph.D. at that time?"

Randall: "I wrote a paper as an undergraduate that has never been cited, and it was on positron physics. And I realized I'd made myself rather impractical and so then I transitioned. And I got a first, and so then people said, 'Oh, you should not do a master's,' I was going to do a master's, and then they said 'You should do a Ph.D.' and I met David Barber, who invented the ion beam thinner, and they told me about this project on ferroelectrics with BLESSY and it seemed interesting and he was incredibly bright and I liked the idea that we would be working with industry as well as working on this new way of looking at materials that people hadn't done before. And that was a very good decision that I made. And I had excellent mentors."

De Guire: "As a first-generation person, how did your family react to this business? Did they ever say, 'Clive, are you ever gonna really stop going to school?'"

Randall: "It's funny. After my bachelor's, I remember going to my cousin's wedding and my uncle thought I was lazy and avoiding reality. It was a farming community, right, so the culture was what the culture was, and in fact I think most of the scientists in our community work enormously long hours. Sometimes I envy the farmers."

De Guire: "I can understand that."

De Guire: "So, it sounds like materials science was not your initial goal, that you sort of discovered it along the way."

Randall: "I liked the fact that it spans engineering all the way through to fundamentals. And so I believe that within a career if there are ways of transitioning something, working with industry, then that's possible when you're in physics, but I saw the opportunities being greater within the ceramics community. And actually for twenty years at Penn State I also ran a National Science Foundation IUCRC program, which had thirty companies in it, all in the dielectric/piezoelectric space."

De Guire: "And ferroelectrics, of course, has become an enormous, and piezo too, has become a huge industry.

And so what would you say, how would you describe to somebody who maybe isn't familiar with our field what the impact is of the kinds of research you're doing with making things on the nanoscale and processing and understanding the properties?"

Randall: "The whole communication, computation, and now the even more electrification of cars are requiring more and more electronics to be around them. And even though most of the glamour publicity is around the silicon chip, for every silicon chip to function, you've probably got so-called three hundred decoupling multilayer ceramic capacitors. So there's one chip, three hundred multilayer ceramic capacitors. And they all have to then be reliable under extreme conditions, particularly for the automobile applications, higher voltages and so forth, and that's where this understanding of the defect chemistry, mixed ionic conduction, and all the things that would be a problem regarding the reliability and the failure of your laptop or worse your car. And how annoying it would be that you couldn't get your Facebook contacts."

De Guire: "That would be tragic."

De Guire: "And then you're the director of the Materials Research Institute at Penn State so can you just tell me a little bit about what the mission of the MRI is? Who's involved?"

Randall: "So there's 300 faculty members that are affiliated or co-hired onto that institute. We have an interesting structure at Penn State where we have the normal department and dean structure, and then you've got five institutes that then go perpendicular or orthogonal to that structure and our job is to really drive interdisciplinary research. And those other institutes include cyber and data, social sciences, energy and environment, and life sciences. And so working with this group in this orthogonal direction really means that you are in a continuous mission of learning from each other and that's the great part of a job like that.

And then trying to recruit really open-minded, cross-disciplinary scientists, and particularly those with bigger visions then just maybe understanding the physics or the chemistry of what they're working on for their Ph.D., is trying to recruit people who will have an impact later on is really also an important part of that, the recruitment part of faculty."

De Guire: "So the MRI spans well beyond ferroelectrics work."

Randall: "Oh gosh, yes. And rightly so. I should be fired if it was just turned into the ferroelectrics institute."

De Guire: "Do you do things at the MRI to encourage cross-fertilization of ideas? To kind of bring in perspectives from fields afar to what other people are working on?"

Randall: "Yeah, absolutely. Even as simple as a Tuesday morning Millennium Café where we serve good coffee and we have scientists from the physical science side talk. And we also have one in the life sciences. And it's usually a way of new faculty to Penn State introducing themselves to a community. It can stretch into the arts, it can stretch into the humanities, but it can also have this real crossover in this area of convergence, which is becoming very popular. And seeing how the materials science can then be linked to the life sciences."

De Guire: "What about cognitive sciences?"

Randall: "Yes. So, absolutely. We've got scientists that are working on sensor technologies that you would wear and linking those to depression, and also other things like Alzheimer's and other things like that. I think materials scientists, and particularly the electrical materials scientists and electrical engineers and materials physicists can often come up with a sensor. But then finding the right community for them to then apply that sensing technology to then develop these complicated things, as complicated as brain behavior. Now we're making materials out of 2D-type materials, so it's a little bit on the periphery of ceramics but it shows where that crossover is."

De Guire: "Right, right."

(music)

SECTION 2

De Guire: "As Clive said, interdisciplinary collaboration plays a huge role in materials science, as discoveries made by materials scientists can be used to create devices for applications in other disciplines, such as the life sciences.

But for Clive, there is one application of ceramics that he is particularly passionate about—and that is ceramics for humanitarian initiatives."

Randall: "These humanitarian programs I think are also quite inspiring for kids that are coming into a science and they've got to Thanksgiving and talk to grandma and she says, 'What's this ceramics business? What's this materials part?' but now they can give her some examples, sensors and making nozzles of aircraft and enabling high-temperature, more efficient engines and so forth. But then also saying, 'Well, we're making point-of-care water filtration, do you know that 25,000 children die of drinking bacteria in contaminated water? Here is a way of controlling that.' And so I think those messages get across. Talking about barium titanate or 2D materials and things like that, it will be lost in terms of the general public. But there are many, many other things that I think these types of programs, 'Oh, that's what we do.' I thought ceramics were toilets or pottery. It's much more than that, even on a functional level."

De Guire: "Do you know if there are any active programs in deploying water treatment systems based on ceramics?"

Randall: "Yeah, there's many companies out there, even making pots. Like one of your sponsors at this conference [ICACC 2020], Imerys, has got programs like this, making them in Pakistan, for example. I went to a national lab in South Africa where they had a whole R&D facility in one of their national labs, all worrying about various forms of water treatments."

De Guire: "And then that also builds up a localized business with employment and other things that go with commerce."

Randall: "United Nations Sustainability Goals, one of them is employment, some of them are in water quality. And so this is absolutely intermingled to this. And materials people play an important role here."

De Guire: "So do you think that there's a role here for us, from first world countries, to build a workforce in terms of exporting our knowledge of ceramic processing and ceramic systems."

Randall: "Absolutely, in part. But also, us understanding maybe the machinery and what's enabling for them. So it's not just taking the highest milling media and highest energy and best furnace technologies that we're using. It's like what can you do, but maybe using the understanding of zeta potential in terms of milling and dispersion, can you then use that in a way that would be useful. And just even using more natural assets like acetic acid or something very, very simple to just try and get a stronger laterite brick, for example, that isn't going to wash out in a monsoon because its mechanical properties improved by better dispersion and better processing."

De Guire: "So it sounds like there's a very creative aspect also to working with these kinds of problems because you're limited by what the local resources are. And it's not exactly that it's a limitation, but it's a different set of resources than what we might be used to thinking of."

Randall: "Yes. And when we were kids, you could work on your car to keep it going. It's impossible to even hardly find the battery now and put the right fluids in. And so there's a whole skill set where a lot of people are going into an engineering subject and are not comfortable even changing the tire on a bicycle. But giving them the tools and the right types of hands-on training, and even framing it in this very simple way, making them see that if you peel an industry down to its core in terms of the rheology and the dispersion and so forth, and take it from a classroom on colloidal particle sintering study and map it onto solving a problem that could help a remote village in, I don't know, Tanzania."

De Guire: "And I know The American Ceramic Society has been working a little bit on developing some humanitarian activities and you've been a part of that. Can you just update us briefly on kind of where we are with that?"

Randall: "Yes. So, I mean, in Portland at that meeting [ACerS Annual Meeting at MS&T19] ran the very first sort of pitch competition. So even just getting people to think in almost a Shark Tank type of idea, that you have the humanitarian materials problem and you have these teams. And I'd like to see that being developed more because it allows then the students to realize that you have to think differently about cost and supply chain and the problem that you're trying to solve and the skill sets and the sustainability of the solution. And it may be very different than working for a company in the United States, for example. So it's a different skill set, but it touches again on the rudimentary parts of all decision making. And it's something they can be very proud of."

De Guire: "I did have a chance to go to that, and they were really impressive presentations. I was really impressed because of all the reasons you cited, you know, looked at local resources and local infrastructure, what the realistic costs were going to be and tradeoffs. It was really, really well done."

Randall: "I think for young people, they believe that their careers are about high-impact papers. It's very important to have high-impact papers. But, for example, and I've got a reasonable so-called Hirsch index, right? But it's not the most important thing. And I think there is a drug that people are now feeding off of that. It is somewhat dangerous and naïve.

Back in 1970s, Rustum Roy talked about another type of h-factor called the human impact factor. And it's in his book of Experimenting with Truth. And at that time the number one thing was nuclear war. And it's before the internet, before all those sophisticated things like television in terms of the home and so forth. But it was about a number of different factors, that if you do the same analysis from a sort of figure of merit on human factor, then the climate is the most obvious thing that as engineers and as scientists we have to now do. This is now getting so serious that without having our research directed towards those types of problems, an h-factor, people who put it on their gravestones as an epitaph, I don't think so. It's telling our grandchildren, or our grandchildren speaking of the scientists at this time that managed to do something and tell their children that, 'Oh, that was something your grandmother did' or 'This is something that your grandfather did' is much more important."

De Guire: "I agree with that. I think scientists are and engineers are, and especially researchers are uniquely positioned to solve in a substantive way the big problems. And I think that's one of the reasons why it's so important to publish. Because a lot of people, just in their daily lives, can recycle everything they own and it's important and it needs to be done, but it won't really advance the needle to the degree that it needs to be. But people in research who have the talent and the skills to do that, they can really move the needle."

(music)

SECTION 3

De Guire: "Clive himself has been involved with moving the needle in research in a number of ways. But one of the main ways he's been moving the needle in recent years is by championing a radical new idea—cold sintering."

Randall: "I found myself back in 2012 reading books in the geological area and just interested in understanding a little bit more. And then there was a group in Finland that then showed room-temperature sintering of lithium molybdate and it was very clear that that work was using some of the kinetics and processes that were potentially at play in the geology of the earth in sedimentous rock.

And so immediately we started to work with some very, very old Carver presses, which were 40 years old, and I knew that we needed to play temperature, I knew we needed to take into account particle sizes, and we needed to control surface chemistry to control the interactions of very, very small amounts of solvent and the interactions with the surface. And almost over a period of six months we went from maybe three or four different examples to almost sixty different types of materials that we could densify. We kept expanding from very simple layered structures to then close-packed structures, various different crystal structures, various different ionic and covalent bonding mixtures, different chemistries. And the whole secret lies within the use of a very important transient phase that comes and goes. As I've said, it's going to be an open system, and then controlling that to then drive all the molecular species that are then needed to drive the sintering densification process.

And also very quickly we realized that by going from these typical temperatures, you know, the Ashby diagrams show that it's 0.5, the homologous temperature over the melting temperature, the 0.95, these really high temperatures, all the mechanisms described as, we're at 0.1 and 0.2, right? And it's shifting sintering temperatures by factors of ten, and so it then pushed things into a regime of where processing with polymers is possible. So now you can make completely different types of materials. Maybe they're bioinspired, maybe they're just allowing a pathway to even a cyclic economy where you can rid of a nanometer of polymer at the end of life and for a very low temperature process and regain like barium titanate powder, the components of a battery, whatever. A brick, maybe."

De Guire: "So you are already experiencing some industrial interest."

Randall: "It was done in secret for two years before we even made a public announcement and the patents, and it was done within the Center for Dielectrics and Piezoelectrics at Penn State. So there was company people watching it from right at the beginning."

De Guire: "Do you think it will, what industry do you think will be the first to adapt the technology?"

Randall: "Well, I think because a lot of those people were in the electronics space, I see it could be in the packaging area, there's lots of interesting properties for microwave-based applications and antenna applications. We see pathways to capacitors; we see pathways to medical ultrasound. But it maybe proves we are biased because of our previous training."

De Guire: "That's possible because it's what you have the most knowledge of."

Randall: "It's nice to see other universities now not only reproducing what we have done and pushing it in new ways but also now starting to think about what in the other areas could be looked at. And it is an important step. I mean, sol-gel, I remember when sol-gel was around many, many years ago and how that become an important industrial process for producing alumina and other things. And we hope that this will be a fast transition out of the laboratory and into production. Because at the end of the day, we are needing changes in the way we make things, we cannot continue with the way we can. We have to be absolutely aware that there are enormous pressures on industry and the CO_2 footprint that we are leaving with the present-day processes."

(music)

CONCLUSION

De Guire: “Materials research is about more than technical impact. It’s about having a human impact that helps improve people’s lives, as Clive is doing with his research on cold sintering and his activities leading The American Ceramic Society’s Humanitarian Activities Network.

I’m Eileen De Guire, and this is Ceramic Tech Chat.”

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