CERAMIC TECH CHAT

Episode 17

Title – "Diversifying energy sources and workforce: Sossina Haile (E17)"

INTRO

De Guire: "I'm Eileen De Guire, and this is Ceramic Tech Chat.

> In August 2021, the United Nations Intergovernmental Panel on Climate Change released its sixth assessment report that addresses the most up-to-date physical understanding of the climate system and climate change. For the first time, the IPCC described the role of humans in climate change as 'unequivocal,' and the United Nations Secretary-General António Guterres said the report is nothing less than 'a code red for humanity.'
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> While the report does contain ominous warnings, there's also hope. Many of the renewable energy technologies that are needed to reduce reliance on fossil fuels are in development. What they need is proper investment to reach commercialization."

Haile: "If we make the investment, then the technology readiness is very likely to follow. Of course, you can't say absolutely every technology can work out, there will be dead ends and so on. But if we don't put the investment in, we know it will not be ready."

De Guire: "That's Sossina Haile, Walter P. Murphy Professor of Materials Science and Engineering at Northwestern University in Illinois. Sossina's research focus is materials for sustainable energy, with an emphasis on fuel cells.

> What are fuel cells, and what benefits do they offer? Also, diversifying our energy sources is just one step toward a sustainable society—today we'll talk about how to engage a diverse workforce as well."
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> (music)

SECTION 1

De Guire: "So has your entire career been as an academic?"

Haile: "For the most part I've been in academia. When I was an undergraduate, I had absolutely no desire to go into academia, just zero. I wanted to get my degree and start making money. In high school, my family was living below the poverty line, so I was like, 'I'm done with this. I'm done with eyeing what item of clothing as a high schooler I was going to buy by saving up for two months to buy this really exciting shirt.' I was done. I just wanted to get a job.

What happened was that I started to do undergraduate research and recognized how much control that gives you over what you're doing. That you could really follow a direction, with passion. And then my first summer at the undergraduate, I worked in a development lab. It was ceramic development lab, but it was very much manufacturing, and I found it incredibly constraining. Now in hindsight, I think that means you have to have a lot of innovative thinking in order to solve problems with such a huge number of constraints.

When you're doing scientific research, the number of constraints that you have are actually quite small because you can go in any direction. You don't have to worry so much about how much it costs and how much the manufacturing line is going to have to be retooled and how much all the employees are going to have to be retrained. You just don't have those constraints. So you have this blank sheet of paper, you can use all the creativity that you like, and that is about the science. Whereas in engineering real-world situation, you have to come up with solutions that are just incredibly constrained. And for me that was just not interesting. There were just too few levers that I could envision to solve this problem.

And, it was actually interesting. I was working at IBM that summer when they were switching from copper to aluminum for the vias [in the electronics], which was a big deal at that time. And everything was really confidential, so I didn't like that either because you couldn't talk about it. The students would joke that when you gave your presentation, you had to leave for the Q&A because then everything was confidential. And so it was a really, it was not an open environment, both in terms of how you pursued the research and how you even discussed the research.

So that brought me into thinking about research as a career. I worked at Bell Labs then through my Ph.D. days. And then I was contemplating joining Bell Labs, this was back when Bell Labs wasn't clear what was going to happen. But then it became clear that they were not going to stay at the research laboratory, and so then I joined academia."

De Guire: "Well, it sounds like academia has turned out to be a really good fit for you."

Haile: "Yeah, definitely. I've very much enjoyed it."

De Guire: "That's great. When you were talking about your aspirations as an undergrad, you mentioned that you're from a family that lived below the poverty line. And I believe you're also an immigrant from…"

Haile: "Ethiopia."

De Guire: "Ethiopia, wonderful. Can you talk to us a little bit about what it takes to get over those barriers? Because certainly there's enormous talent that we want to make sure that we do what we can. So, what does it take to get over those barriers that come with living below the poverty line?"

Haile: “The situation I think in the U.S. is very challenging and nuanced. I have been meaning to do just a survey of the faculty who are people of color in STEM fields to see whether they are first, second-generation Americans, or if they have lived here through generations. My overall impression is that they are people like me, who were either immigrants themselves or their parents were immigrants. And that, for better or worse, just produces a different psyche of experiencing life in the U.S. You know, when you come to the U.S. as a refugee, first of all there’s an incredible sense of gratitude for the country that has taken you in. And the second is there’s much less baggage of seeing people around you who are not successful. When I was in Ethiopia as a child, every doctor I knew, every lawyer I knew, every professor I knew was Ethiopian. So there was no question that this is something a person like me could do. Maybe you could argue, ‘Okay, they weren’t very many women in those fields.’ But, you know, my parents supported me in my pursuit, so that was not an issue. So when you grow up in the U.S., you don’t see that.

I didn’t recognize how important that is until much later in life because I came to the U.S., and it just didn’t occur to me that, just because I come to a classroom where everyone else is Caucasian in small-town Minnesota, that that had anything to do with me. I mean, it just is what it is. That’s why I came, right? But now I understand that if you are having to fight that and what it means to your own self confidence and self vision of who you are, that that can be really traumatic because you may be in the region of the city of Chicago where what you see around you is failure and you see on television success of a different group. And that, I just have to presume that that does something to a person’s psyche. And that becomes something very, very difficult to solve within our confines of The American Ceramic Society or the confines of our academic institutions. So we have to think, you know, what is society saying and how do we change that broadly.”

De Guire: “Well, thank you for sharing that experience. It’s definitely thought provoking. I think one of the roles for the Society is to really make people visible and make the successes visible, and we can do that through awards and committees, those kinds of things. I think it’s a start. And a start is the most important thing because then the journey reveals what the next step is, I think.”

(music)

SECTION 2

De Guire: “So, what is your research focus there at Northwestern?”

Haile: “Speaking in terms of the scientific description, I’d call it solid-state electric chemistry. In terms of the technology description, I would say it is materials for sustainable energy.”

De Guire: “And how did you get interested in the idea of working on sustainable energy issues?”

Haile: “Certainly all throughout my life, thinking about what I would do as a career, I had the idea of something that would be in service of society. But along with that I would say it

also had to be something that was scientifically interesting. Being at the frontier of just doing something that was exciting.

When I was doing my Ph.D., I was actually looking for something much more in the biomedical area, but that was, I would say, ahead of its time in terms of my idea that would bring together medical sciences with engineering. And I ended up looking at materials that have high ionic conductivity, means that ions move through them quickly, and that has relevance to batteries. And so that sort of led me to the overall idea of solid-state electrochemistry, which then relates to technologies such as batteries and fuel cells, electrochemical synthesis of fuel using electricity, and so on."

De Guire: "It seems like battery technology is really coming into its moment. As we're moving in the direction of electric vehicles and other green technologies, battery technology is really kind of at the core of what's going to help make this work. So, what are the key technical issues that you see that we still need to solve in terms of materials?"

Haile: "Right. So, batteries are definitely at the frontier of what we're doing in terms of storing electricity in order to be able to then use it on demand. And when I say we, I mean society in general, not very much in my laboratory. Batteries really account for less than 1% of all grid storage currently, and grid storage needs to be expanded dramatically if we're going to be able to move away from fossil fuels and do everything entirely by solar and wind. So, there's a huge, huge need to figure out how to store that green electricity. And it's not clear that batteries have a pathway to get there.

So, in fact, what we do in my group is think about different ways to store electricity in the form of chemical fuels. Be that hydrogen, which is a relatively easy fuel to make but a difficult fuel to ship to different areas. But if you can make a cell that can reversibly create hydrogen and then use that hydrogen to generate electricity on demand, then it's an alternative to batteries because it becomes a storage system where you are storing the energy, not in the device itself, but in a tank. So you're using the device just to create the chemical fuel that you're storing. And it gets around some of the challenges of batteries because the battery, if you want to store more, you have to make the battery bigger, you have no other option. But this is much more like a tank storage. So you just keep making more and more hydrogen, you have the tank, and you make it the size that you need, and your device doesn't have to change size when you are creating the fuel for the storage."

De Guire: "That's really interesting in a really kind of different way of thinking about how to store energy for a sustainable economy. And we've been hearing about the hydrogen economy for a long time. This seems like one of the first really pragmatic steps towards executing a hydrogen economy that I've heard about. Are there other trends out there that are pushing us in the direction of a true hydrogen economy?"

Haile: "I would say there are. Certainly the political trends are pushing us back to that direction. The Department of Energy has just announced its Earthshot. So there was of course Moonshot and then there was SunShot to get solar energy to be cost effective, and now here we are pushing Earthshot, which is to bring the cost of hydrogen production down.

And there are lots of different ways that one can use electricity to break up water molecules to create hydrogen, and then you just release oxygen, which isn't really needed.

So the challenge certainly has remained in the infrastructure, but one of the ways to address that beyond what I've just described to you, which was a reversible cell, so you just use it on site, and it operates very much like a battery, except as I said, you don't have to make it big when you want to have more storage. The alternative, which is harder still, is to make ammonia using electricity. And ammonia is an NH_3 molecule, so it has nitrogen and hydrogen. So very similar to water, except that the carrier is nitrogen instead of oxygen. And ammonia itself has a high energy content in contrast to water. And so ammonia can be liquefied and transported much more easily than hydrogen can. And we already in this country and many other countries have ammonia delivery infrastructures because we use that in fertilizer. If you can make the ammonia using electricity, as opposed to using hydrogen that's derived from fossil fuel, which is what we do today, then you have a way of storing electricity in a chemical fuel that is easy to ship. Now, you know, you don't really want to put ammonia into a consumer vehicle. It's quite toxic. So you'd like to have a device that can convert the ammonia on site into hydrogen. And that's another area where we've done research using our electrochemical devices, that means electricity in and some sort of desired product out. In this case, it's ammonia in, hydrogen out, which you could then use to fill up the hydrogen fuel cell vehicle that you have. And your hydrogen fuel cell vehicle is an electric vehicle that has water as its byproduct. So, it has all the benefits of an electric vehicle that a battery has, it's simply that you're using hydrogen for the energy source."

De Guire: "Well, that's fascinating. And with ammonia, you also get three hydrogens instead of two. So, you mentioned solid oxide fuel cells or maybe just fuel cells, and I know you've done a lot of work on fuel cells. So, how does that technology fit into some of these ideas about sustainability that we've been talking about?"

Haile: "So really it is the fuel cell that makes all this possible. A fuel cell means that essentially we're taking fuel in and producing electricity. So we're producing electric power. We can make these devices reversible, so we call them reversible electrochemical cells, so that we can take electricity in and produce, for example, hydrogen, which is our fuel of interest. Or, if we're very creative in terms of the catalysts, we can directly make ammonia. That's still further down the line, but there are pathways to get there. And so we're simply expanding the function of our fuel cell from being a one-way device to being a two-way device, so that it can do the storage piece as well as the electricity generation."

De Guire: "And in terms of technology readiness, how close are we with some of these conversion technologies and solid oxide fuel technologies to deploying them and seeing them contribute in a real way to a sustainable economy?"

Haile: "Yeah, it's still a challenge in terms of technology readiness. You know, 10 years ago, we would have never thought that lithium-ion batteries could have an impact in the marketplace in such a short time. And I think it takes that same investment to say we're going to be on this track and push it fast and hard because the planet needs it. And so

technology readiness is something that we know where it is today, but to predict where it will be in 10 years, it's a human choice. So, there are technologies that could have an impact on the timescale that's necessary, and when we think about this, the latest intergovernmental panel report on climate, we have to get on with it. And so, they have the potential to make a difference if we put in the investment."

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BREAK

De Guire: "The American Ceramic Society's Energy Materials and Systems Division focuses on stimulating the growth and activities of the Society in the art and sciences pertaining to ceramic and glass materials for energy-related applications. Learn more about this Division at www.ceramics.org/emsd."

SECTION 3

De Guire: "What is the next breakthrough that we really need to see happen in these areas that you're working in?"

Haile: "Boy, to pick just one. It's perhaps less inspirational than what one would like to hear. It's probably about the manufacturing. So how do we scale up the manufacturing of the components that we already know how to make, of those fuel cells, of those electrochemical cells that we know how to do, that we've demonstrated in laboratories like mine that have the stunning, awesome performance that end up in publications in *Science* and *Nature*, but how do we take it from that into an actual device that someone can deploy. That is some very serious engineering, some very serious innovations in fabrication. Unfortunately, it doesn't produce the exciting publications that get you a lot of respect amongst your colleague, if what you're working on is making the ceramic sinter more effectively at a lower temperature and therefore can be mass produced.

So that's the innovations that are needed. There are certainly other innovations in terms of the fundamental science, which I described in terms of how we do the ammonia electrochemical synthesis. But I think that's a really exciting science breakthrough that needs to happen. There are some people who say that they've been able to do it, but the rates are really very low, and there's a lot that needs to be done. Even electrolysis to produce hydrogen from water requires continued development efforts. So, there are pieces that are the exciting finds that still need to be done, but given the technology readiness we have today, I think that the manufacturing efforts really, really need to go forward."

De Guire: "And that brings up the issue of collaborating with industry. Do you sense that industry is ready to take this challenge on?"

Haile: "Boy, I would like to say the answer is yes. You know, I understand that from an industry perspective, making money on a relatively short time frame is essential, otherwise the company is not in business. Universities have been around, many in the U.S. have been

around for over 100 years, maybe even 200 or 300. So they're not really at risk of an existential threat if they don't make the success. For companies, there is an existential threat, especially if they're not doing something which is adding to the bottom line in at least the two- to three-year time frame. So it's hard for them to make that jump to say we're going to put this big investment in.

And that's where government has to come in, to make sure that the incentives are in place, to show that this is a direction that can be fruitful. Either by direct incentives or by policies that say, 'Yeah, we're not going to have fossil fuels anymore, so you better think about what else you're going to do.'"

De Guire: "Okay. Can you talk to us a little bit about how you first encountered The American Ceramic Society? And then what it's meant for your career over the years."

Haile: "Yeah, I was probably in one of the last classes at MIT that was taught by David Kingery. And we used the textbook, Bowen, Kingery, and Uhlmann. So I took courses from all three of those individuals, and it just got me really excited about the field. I attended The American Ceramic Society conferences. And, you know, I would say that in general professional societies are ones that help you make connections, and certainly The American Ceramic Society has been important for me in that way."

De Guire: "Great. At present you are a member of the ACerS Diversity & Inclusion Subcommittee. So I wondered if you would talk to us a little about the activities of that subcommittee and what the goals are that the committee is trying to achieve."

Haile: "Right. First of all, let me give credit to others who are perhaps more active on the committee than I am. I certainly view that it's important to participate in such efforts. It's also a challenge when one is sort of the small representation of diversity. You get pulled on many, many different committees. That said, this particular committee I think has been working hard to make sure that we have diversity represented across the Society, in terms of who the speakers are; how we bring new members into the Society, we welcome them in; and how we make sure, for example, things like awards are distributed in a way that's equitable. And just generally ensuring that the Society is broadly welcoming and helps to advance the careers of those who may have been otherwise overlooked."

De Guire: "Great. And we thank you for that work. It's really important, and we really need as many voices as we can to get that done."

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CONCLUSION

De Guire: "Diversifying our energy sources is a crucial step toward a sustainable society. And it's important to diversify our workforce to bring as much talent as possible to tackling these challenges.

I’m Eileen De Guire, 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 Sossina’s research on materials for sustainable energy. Ceramic Tech Chat is produced by Lisa McDonald and copyrighted by The American Ceramic Society.

Until next time, I’m Eileen De Guire, and thank you for joining us.”