CERAMIC TECH CHAT

Episode 32

Title – "Big picture, small scale—connecting materials and communities: Sanjay Mathur (E32)"

INTRO

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

> When transitioning from student life to your professional career, it can be intimidating talking with established researchers and finding your spot within a community. Fortunately, many senior members in ACerS are passionate about supporting the next generation and lending an ear to their ideas."

Mathur: "Important point for me is really to have an open conversation. We have room for improvement, to grow. So, do reach out to me because the best motivation for any volunteer is to get the direct feedback."

De Guire: "That's Sanjay Mathur, this year's president of The American Ceramic Society. Sanjay is director of the Institute of Inorganic Chemistry at the University of Cologne in Germany. His research focuses on hybrid material interfaces and their properties, including energy and biomedical applications. He also is well acquainted with interfaces with interpersonal relationships through his volunteerism with the Society.

> What are the challenges and benefits of mentoring students within a university setting? And how can societies like ACerS provide additional support for students and help them lay the groundwork for a professional career?"
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> (music)

SECTION 1

De Guire: "So, let's talk a little bit about how you got started in the field of materials science and engineering, and specifically ceramics."

Mathur: "I would say it's a nonacademic path. I come from a small town in India. Back then, when I was growing up, there were not too many opportunities for entertainment and sports engagement. So very often when there will be no school, my grandmother, she will take me to these moving potters villages. So these are some groups of people, and they will come with their expertise of making clay articles. And these villages are coming into existence ahead of the Indian festival, light festival, like the Diwali Festival of Light. And then they will come with their families. They have kids, they have the animals.

And what they will do, they will play with clay, I mean, they will make slurries. I think this was my first experience without having any idea of connecting to science or how human fingers can also do additive manufacturing, because they will do all these beautiful pots and statues of gods and goddesses of India, and they will make earthen pots of terra cotta. So it was very interesting to see, just by touching, how could they adjust the consistency of the slurry and then give it in different shapes. And if you hang around, or I used to do that for a long time, they will once in a while also make a small toy for you. That was my reward often. That's why I love that.

And I must say, I had no bridge to science at that point. But this was amazing to see the artistry, the skills. And once again, I'm firm believer of that education give you lots of skills, but when it comes to your calling for a particular profession, that kind of vocational training is just in your DNA. So seeing the small kids also making the same that the grandfather was doing.

And then I will always, I used to wait and watch, because these, or the green body, they will be, and we have the rooftop oven. So, how sustainable the whole model was. They will go and collect wood from the nearby forest, and then these earthen potwares will be fired. And I used to wait for the moment because when they will take out, many of them will just break when they are cooling down. Today I understand that this was due to thermal stresses. But that time it was just amazing to see that even if everything is same, certain things just don't work. But why they were dysfunctional, I had no clue because I was just too young for that."

De Guire: "Right, but it started that curiosity, that observation, and then starting to understand what was different."

Mathur: "True. And this is what my personal journey has taught me, that somehow things connect to each other. So when I started my doctoral research, I was working on sol-gel chemistry. And then I realized that all that gel with lanthanide or dye-doped to make colorful things. So it's very similar to what I have seen, but now I knew that there is a metrics, there is a lanthanide atom that can be photoexcited. But the beauty that I enjoyed in observing things was almost similar to the joy I had in doing things. So I think that there is a connection if you have…And science is all about observation."

De Guire: "Right. So, coming to today, what is your research focus now?"

Mathur: "So I'm a materials chemist by training, and I think the training in chemistry has shown me that everything which is being held together there are chemical forces. And the same thing I realized that when things are not working, if you have a joining of two different materials, like ceramics and metals, two ceramics, it's always the interfacial chemistry. So that's why I've been a firm believer that chemistry is very, very intrinsic to materials development and functionality. So, I think from that viewpoint, I've stayed very, very loyal to my training as a sol-gel chemist, and I always use that path to develop new materials.

Today we work mostly on nanocrystalline powders and ceramics, which can be functionalized. And that bridge of connecting small molecules to an extended material like a solid nanoparticle or a macroparticle is a hybrid interface where a lot of new properties are generated."

(music)

SECTION 2

De Guire: "Are there any areas where you're looking at this materials chemistry to solve a certain kind of application?"

Mathur: "We are working on three major areas. One is materials for energy development. Here the focus has been on new photoabsorber material, and the dream reaction is to split water using sunlight to create hydrogen. That would be most sustainable way to have an energy carrier, which can then either be converted into a secondary fuel with different calorific value, or it can be used as a fuel for solid-oxide fuel cell to generate energy or to run chemical reaction, like reduction of carbon dioxide.

The major challenge so far has been, and this is where I see that ceramics are so essential to the energy problem of climate change. Because right now we don't have materials which are going to be stable under electrochemical condition. They start degrading. That's why there are out of academic realm, there are no materials which can be used. But if you see the evolution of our planet, something which has survived over millions of years, there are rocks, they're all oxide kind of rocks hiding materials from me. And if you can find them, and that's where we are working: a material which can harvest maximum photons coming from sun and drive chemical reaction. I think nature is doing it by photosynthesis, and that's why we're interested in artificial photosynthesis. It's coming from the fact that we can make artificially; they are not going to regenerate themselves, but they can run sustainably by a right photocatalyst and split water. This can be sea water, where you already have electrolytes dissolved.

So, this is one area of energy. And then we do work for several years now on hybrid perovskites. And here also there is a chemical combination because the hybrid perovskites are easy to make, they are cost effective, solar cells can be made out of them, and they can be then used to split water. So, you have a tandem set up. You have photovoltaic harvesting, the photon or photonic energy, and then this can be used to feed into electrochemical cell to split water.

So these are the two major areas. And then we work a lot on nano–bio interaction. How we can use ceramic particles or glass particles for drug delivery and select a targeted drug level. Because here the motivation comes from the fact that we have so much of advancement in medical chemistry. We have every day new molecules being discovered. We have so much of understanding on molecular signaling pathways. We know where the new targets are. We have an understanding of tumor. But still, when we look at how the drug is administered to someone who has got a tumor, we are flooding the system with a

toxic drug, and that system flooding has to be changed if you are thinking of human well-being. And here these nanocarriers, nanocapsules, which can be used for drug delivery, they play a major role. So this is our second area of nano–bio conjugates.

So, as I mentioned here again, the chemical feature is important. How can I make a nanoparticle so interactive that it can be connected to a biomolecule, like a protein, a peptide, or another macromolecule? And this is something which is going to become more and more important when you want to do things targeted. And that's what the targeted drug delivery is. That you are able now to drive that drug to the sites, which are generally called undruggable sites, because the drug will not reach there because of the pathological or biological barrier."

De Guire: "Right. Very interesting. Do you think there are applications for drug delivery that are not related to cancer?"

Mathur: "Well, yeah. There are a lot of like…Looking at the best example is skin. The good thing about skin is that you have a direct access to the organ. Everything else, when we talk about tumor, whether it's liver tumor or breast tumor, you have to go inside the body. In the case of skin, you have direct access to the organ. And there are lots of skin diseases where you have issues in healing. And here again the nanostructured materials, which are imitating the cellular matrix, they can be used for accelerating the wound healing, for example, or for slow drug release.

Second area where we are working is on the eye. So interestingly, there are not too many approaches if there is any kind of impairment in the eye because the eye has a very heterogeneous construction. So if you have to bring a drug to the retina, you have to go through different compartments with very different structure. So this is where you can again think of having these nanocarriers, which can be locally injected, because that's a thing. Most of the drugs are then given by local injection.

So, there are several areas. I mean, skin and eye are just two examples where we work. But I can imagine that when we talk about regenerative medicine."

De Guire: "Right. That's an exciting new field."

Mathur: "Right. So bioceramics, how popular it has become because it is helping human being. That is, it is a direct impact of ceramics research on human well-being, human health."

De Guire: "Yeah. Thinking back to now the hydrogen and water splitting. How close do you think we are to a hydrogen economy? What are the challenges we have yet to overcome to really use hydrogen as a fuel?"

Mathur: "So I personally believe that this approach of having a green fuel or green economy or decarbonization of economy has to face the major challenge. Because energy transition is a materials challenge, right? So you need materials whether it's energy harvesting, energy storage, like hydrogen can be produced, electrolyzers are producing it. But the issue, we

don't have good storage materials. So if the production is expensive, storage is expensive, and its dispensing is expensive because there is an explosion potential there, then obviously, the whole energy cycle is not working well. And this is where we talk about levelized cost of energy production to reuse, or use or reuse.

So, I think we would need, and I'm sure that ceramics will play a very important role. The whole revival of the solid oxide fuel cells and all-solid-state batteries, they are putting ceramics in a much larger frame. And this is where I think it's also, now looking from our society perspective, it's so important to do everything to bring ceramics in the center of many of these challenges. And it's not that we are overdoing. That's the reality. We need new materials which are functional, which are more active, earth-abundant, recyclable. And this is where I again come back to ceramics."

De Guire: "Great. So you're a professor. Had you expected a career in academia?"

Mathur: "I was always very inclined to teach. I was not sure that I will become a professor because there are several other careers. When I started my career in Germany, and there you have the possibility of also growing up as a tutor, never become professor. But the good thing is, you can be very close to students, mentor them. You don't have the pressure of writing grants, bringing third-party funding. But professorship was something which was also a path that a lot of people have helped me to follow. And I think I was well prepared through all these mentors to take this challenge. Looking back, I think I would have not been, my happiness would have not been the same if I would have taken any other job."

De Guire: "So what is it about the job you think that makes you happy?"

Mathur: "Yeah, that's a very interesting question because I always say that this is a very privileged occupation. All those who are able to interact with younger minds, and these minds are getting younger every year. So that's recalibration process. It keeps you mentally fit, first thing. And second thing, when you see how your students or your mentees are succeeding, it gives you such a satisfying feeling that that you cannot gain or get from anything else. So that is something where you feel responsible.

And sometimes, that's why I say it's an interesting point. It's a challenge. A professor is obviously professionally goal oriented, success oriented. Mentor is not doing that. Mentor is more interested in the success of the mentees. And if you want to lump these two people in one personality, that's not easy because the pressures are different, right? And this is where I think it keeps you going, it keeps you motivated, and then the possibility of like doing what you want. I mean, you can change your research area as you would like if you have a smart idea and the funding agencies, and you are able to convince them, they are not going to say no to you. So, this degree of freedom you don't get in many other professional sectors."

De Guire: "That's true."

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BREAK

De Guire: "When you join The American Ceramic Society, you join a group of more than 10,000 ceramic and glass professionals and students from more than 70 countries around the world. Regardless of where you are in your career, ACerS' various membership options allow you to network with people with similar interests at a level that works best for you. Learn more about ACerS membership at www.ceramics.org/memberbenefits, and consider joining our community today!"

SECTION 3

De Guire: "So you talked a little bit about how satisfying it is to be a mentor. But what is your philosophy and approach to being a mentor, and how has it evolved over the years?"

Mathur: "So I believe very much in a very democratic process and also very interactive. Whenever we decide something, like buying a new machine, we discuss it in the group as if we were buying something like we do in the family. So they should feel the responsibility that they were part of a decision-making process.

And I also believe in collaborative interfaces. So I always encourage and empower our students to go ahead and find collaborators. And I said, 'I will take the lead and I will bring you there.' If you think that they are smart, so are doing things, or they have a better machine or setup which is very unique. And this is how we have benefitted a lot. And I think if you have the possibility of encouraging a young student, the return on investment is huge because they have a degree of dedication. I might have a great idea, but if I don't have time to execute, that's not going to work. So that's why I've made it very interactive.

I try to share the privileges and degrees of freedom that I have with them. That's why I think most of my group members are traveling with me to many of the meetings. And I have made it always a point, and I think I had more than 80 Ph.D. students have graduated with me. Eighty-four, actually, to be precise. And I think most of them have attended three to four international meetings. Because this is where I see that is changing their personality in a way in which I cannot do. I cannot just tell them what to do or what I have seen. They should experience it. And that first-time experience is very, very, I would say, forming for their career."

De Guire: "Absolutely. And by doing that, you're also introducing them to the community and helping them to start building their professional network, which leads to future collaborations."

Mathur: "Very true. And I think this is something which I was trying to also underline in my remarks here. That we teach a lot of things, what is important, several undertakings, when it's about writing a paper, scientific integrity, ethical codex, and so on. But belonging to a professional organization, or sense of volunteerism, is also an obligation. That has to be

also conveyed, so that they know that I'm not going to a meeting because just someone allowed me. Or I'm not going just because I had to present a short paper and I'm back. No. That's an opportunity to stay connected to my community. And then to come back with this feeling that I am the community, not there is a community that I have to go and join. This is something which is very, very enriching for any young career."

De Guire: "Absolutely. So, that's a great segue into talking about your community. How did you first hear about The American Ceramic Society, and how has being a member impacted your career?"

Mathur: "Actually, that's an interesting point also because back in India, where I did my doctorate research, I didn't have a chance to come abroad out of India. But when I came to Germany and I realized that mobility is here and almost an integral part of any professional career, already master's level students are traveling at Ph.D. So, this is how I started traveling. And when in '98 somebody asked me, 'There is a meeting in Cocoa Beach, Florida.' So, I went to my mentor, and I asked him, 'Can I go there?' And he said, 'Yeah. Who doesn't want to go to Florida?' So I, first, because I had no clue about the meeting, I was just thinking that, 'Okay, people are traveling just because it's a nice place.' But then I came and I attended this meeting and felt that energy I have not experienced before. The discussion, that personal time, that people are giving you full attention as a young.

And then later on in 2000, I had organized or co-organized a symposium, my first invited talk, and since then there has not been like looking back. I had not missed any of the major meetings. I joined ECD [Engineering Ceramics Division] as Division, and I must say that I have also found a lot of great mentors there. Things I've done myself inspired me also to contribute to think of having a new Division on energy materials and systems."

De Guire: "And now we do have one."

Mathur: "Yes. So, coming back to the point that this has been a very interesting journey because somebody brought me. So you have to also acknowledge that there are a lot of people who are bringing members. So, this colleague of mine, he's retired, and I have not seen him in the last 15, 20 years at our meetings. But he left behind his spirit through me. So I have been associated, and I was so much inspired through his work, and he showed me what the value proposition is."

De Guire: "And now you've been able to pass that along to the next generation."

Mathur: "True."

De Guire: "And so you've held a number of leadership positions within the Society. Can you talk to us a little bit about what that meant to you in terms of advancing your research, advancing ceramics, and advancing your career and the Society?"

Mathur: “So first off, I must say that since it’s not the day job of any of the researchers, you are never prepared. So, obviously, I have gone through a lot of positions here, starting as secretary or judging the posters or then becoming vice-treasurer or treasurer, understanding the finances, programming, technical programming. And then standing on the podium and then talking about what this large meeting is going to be about. So in all these processes, you see that there are, it’s a learning curve. You are always discovering hidden aspects which you will not anticipate as a researcher, right? So, these interfaces. It was mostly between member and staff, staff and outside. So, in those terms, I have learned a lot of interpersonal skills.

Second thing is that the Society has given me a real professional identity because coming from the chemistry background, having done most of the time, these processing through chemical methods and chemical routes, it was always a challenge. Where do I belong? What is the DNA of my research? And I could get the answer of that question not only for me but from my community. So now, and after so many years, I can see where I belong and that acceptance within the community.

So here I would really like to stress the synergy. So, the volunteering gave me the identity, and that identity helped me get connected to the community. So, it helped me in my career advancement in Germany because The American Ceramic Society has a very large number of German scientists coming here. So, even if I didn’t have the chance to talk with them back in Germany, I could see them regularly at these meetings. And those contacts were very fruitful and very helpful. And I had a lot of, I would say, silent supporters.

So it has been, I would say, a very beneficial journey for me that I was associated with ACerS.”

De Guire: “That’s great. So, I think what I’m picking up here is, whether it’s in the laboratory or in your interpersonal activities, you are at the interface. It’s the interface that interests you.”

Mathur: “Absolutely, yes. I think you are absolutely right. Maybe you are helping me in coining this phrase that it’s mostly, our research is interfacially driven functional properties and materials. And we all know that at the interface, things are changing. The best example is when you have oil dispersed in water. You just need to put a drop of soap and they start communicating. And ACerS has to become that drop of soap, right? And then we have everything solved.”

De Guire: “There you go.”

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CONCLUSION

De Guire: “With 11 Divisions covering a diverse set of ceramic and glass applications, ACerS offers members an ideal platform to pursue novel materials innovations at the interface of various sectors. With Sanjay’s experience working with both literal and interpersonal interfaces, his year as ACerS president—which you can read more about in the upcoming January/February 2023 Bulletin—is sure to advance the Society’s mission.

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 Sanjay and his research. Ceramic Tech Chat is produced by Lisa McDonald and

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