CERAMIC TECH CHAT

Episode 27

Title – "Modern techniques reveal historic secrets: Katherine Faber (E27)"

INTRO

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

Materials scientists often look ahead to the next big thing. Perhaps a new material, a new device, or a new application space. However, sometimes looking back holds the key to inspiring future research."

Faber: "One of the amazing aspects of having a background in materials science is that it has allowed me not only to look forward to materials and applications of the future, but because of this serendipitous encounter that I had, I've also been able to look back in historical materials. And I think that, in talking to some students, they find a richness in that, that one can acquire and develop within ceramics and materials science in general."

De Guire: "That's Katherine Faber, Simon Ramo Professor of Materials Science at the California Institute of Technology. A former ACerS president and an ACerS Distinguished Life Member, Faber's research encompasses a wide variety of fields, from high-temperature and porous ceramics to historical materials.

What inspires a materials scientist to look back in time for inspiration? And how can paying heed to scientists of the past shape the world we live in today?"

(music)

SECTION 1

Faber: "Finishing high school, I wanted to be a chemist. And due to aspects related to both finances and having a wise brother, Paul, who was a guidance counselor, we made our way to Alfred University to check out the program there. And my brother knew that in this private university was a state university program of ceramics that included ceramic engineering and ceramic art and design. And he knew that because of that, you could attend a private university and pay only state tuition. So we talked to the folks there, actually the dean was available. And he said, 'Oh, you know you come in here, you major in ceramic engineering, and you take all your electives in chemistry, and you'll be a chemist.' And that hooked me. But I got to organic chemistry and said, 'Forget this. Ceramic engineering is much more fun.' I certainly appreciated the application-driven engineering more than memorizing organic compounds. So, that was the start."

De Guire: "Very interesting. And then you went on to get a master's degree and a Ph.D. So, what inspired you to go the whole way?"

Faber: "Well, I think when I finished my bachelor's degree, the job market was not particularly strong, and so the easy way to deal with that is to continue to go on in school. And so I went to Penn State and did a master's in ceramics science. By then I wanted to see what industry was like, and I did that with the Carborundum Company in Niagara Falls. After a few years in industry, I realized that I didn't have a lot of control over what I was doing in terms of what I wanted to work on. And so, although I learned a lot there, I was ready to go back to school. And I headed out to Berkeley to get my Ph.D. in materials science and engineering."

De Guire: "Great. So since then, you've really had an illustrious career in academia and as a researcher. So, can you talk to us a little bit about the research you're currently conducting on technical ceramics and what got you interested in these particular projects?"

Faber: "So right now my group is focused in what I would put into two main areas. One has to do with high-temperature materials that have to do with propulsion, so that could be in aerospace, it could be in stationary gas turbines. Since coming to Caltech, I've also been able to be involved with the folks at the NASA Jet Propulsion Lab, which Caltech manages. And so that brought me into some work on electric propulsion materials. And, in many ways, this has to do with the structural integrity of these materials, and it leads back to my interest in the fracture of brittle solids.

Another area which we focus on in the group has to do with porous materials. So, as I grew up in this field, the last thing you would ever want in a ceramic was a pore or a hole because that would ultimately lead to failure. And yet now when we look at applications of ceramic materials, we can benefit greatly having pores in these brittle materials, either for flow or filtration or lightweight properties. And so it was almost a natural evolution then to say, 'Okay, although we don't want pores there, how do we live with them?' And so part of my group here, then, is able to focus on the design of them [porous solids] and also the tunability of them [the pores]. How can we tune them to get the properties we want in these materials?

So, in terms of how I got interested in both these topics, I really owe it to the Carborundum Company, that industrial experience between my master's and my Ph.D., because there I had the opportunity to work on structural ceramics. That was the time of the very first gas crisis, which I suspect many of your listeners will not even remember. But that got me intrigued with the fact that you could think about using brittle materials as structural components."

De Guire: "Well that's really interesting. And it sounds like the common theme is what you just said. Fracture of brittle materials, whether it's a bulk solid or even a porous solid. I would imagine fracture is an even more important in those kinds of situations because if you're not careful, you end up with powder."

Faber: “Yes, indeed.”

De Guire: “One of your projects is on shape memory behaviors of porous zirconia-based systems. You don’t usually think of ceramic materials having any kind of plasticity or elasticity. So, what are you learning there?”

Faber: “So there was some work done in the early ’80s largely by I-Wei Chen’s group at University of Pennsylvania basically showing that zirconia-based materials, as they go through a martensitic phase transformation, do show shape memory behavior and superelastic behavior. And his students were doing this work on bulk ceramics. And when these materials undergo a crystallographic phase transformation, there is a large volume change in the material. And so, as you can imagine, in a bulk material what happens is you form cracks, and all of a sudden, you don’t have dust, but you have a pile of rubble. And so, this was published in the literature and forgotten because although these shape-memory and superelastic effects were important, they weren’t controllable.

Probably about 10 or 12 years ago, as people began to make materials in the sizes of nanoscale and micron-size pillars, Chris Schuh and some of his colleagues in Singapore said, ‘Okay, why don’t we now go back to that topic of shape memory and superelasticity but use these nanoscale and micron-size pillars, where you have just a few grains, and then this change in volume could be accommodated.’ And that really intrigued me, and I said, ‘Okay, we have porous materials, so why can’t we use these concepts of a micron-size pillar? Now let’s just make the walls thin enough that basically they have very few crystals along the walls, and can they then accommodate the strains and prevent fracture?’ So, I’ve had a postdoc and now a student who have been focusing on this. That porosity is now our advantage.”

De Guire: “That’s amazing, actually. Kind of stunning to even think about. And what kind of applications would that kind of a material be used for?”

Faber: “Oh, I think the main application would be in something like energy harvesting, that you can go through these cycles.”

De Guire: “I see. Okay.”

(music)

SECTION 2

De Guire: “Another really fascinating aspect of your research career is you’ve branched off into a completely different field of cultural heritage, preservation, and understanding of what’s happened before us, mostly in the terms of porcelain arts. So first of all, can you tell us what we mean when we use that phrase ‘cultural heritage,’ and how did you get interested in that kind of research?”

Faber: "To start with, cultural heritage is an extremely broad term. So this would include cultures and beliefs and rituals that have been passed down through the ages. From the materials perspective, it also includes the materials that have been created by various cultures. As you can imagine, we want to not only understand this history, and oftentimes materials will provide that understanding, but we also want to understand these materials well enough that we can care for them and preserve them so that they can be passed down to future generations.

Now how I got involved in this, it's almost a similar story to how I ended up in ceramics. It's all serendipity. During my 27-year career at Northwestern University, I spent a five-year term as department chair. During that term, I was paid a visit by a few folks from the Art Institute of Chicago, which is a phenomenal museum. And they told me that they had received a grant to hire their very first conservation scientist. For the listeners here, a conservation scientist is generally a Ph.D.-level scientist who focuses on the conservation and the study of objects of cultural heritage so that they can be well preserved for the future and also to provide an understanding of those materials for those interested in history.

And they asked me, 'When we hire this person, although [we] have a large conservation lab filled with conservators, we are a bit concerned that that person may not have a community of scholars to interact with. Do you think you and your department might be interested in that?' And it took me about a nanosecond to say, 'Of course we would be.' And about a year later, they hired Dr. Francesca Casadio, who became a collaborator and a dear friend and got me involved in materials projects that, again, I never would have anticipated. In addition to doing some work in my own lab, I was also the matchmaker at Northwestern to point out other people in other engineering disciplines, and also there were links made to chemistry, where we could form an important partnership.

So, through the years, this went from a partnership that was supported by the Mellon Foundation to ultimately the Northwestern University–Art Institute of Chicago Center for Scientific Studies in the Arts, where through a lot of the shared facilities at Northwestern we were able to invite other museums without laboratories to submit proposals to have some of the work done there. And we hired a senior scientist and a few postdocs to do that work. And the Center is still in existence, and I certainly miss being a part of that."

De Guire: "I can imagine. And then, you're doing some current research on historical porcelain artifacts. So, how did it come to be that that became a focus of your research?"

Faber: "That particular project on Meissen porcelains was of interest to the Art Institute. Our collaborator on that project, Dr. Anikó Bezur, was very interested in du Paquier porcelains, which were made in Vienna. And [she] began to notice that there were a great deal of similarities between the Viennese-made porcelains and those made in Meissen, which is outside of Dresden, Germany. And it turns out historically there was an interplay between those two places. Some of the craftsmen would move from one to the other. Sometimes they were captured and taken to another factory because this was so important. We're now talking about early 18th century, where the people in that part of Europe really wanted high-quality porcelain, and the only way they could get it was to import it from China and Japan. And so, there was a push then, and the origin of the high-quality porcelains in Europe came about in the early 1700s.

So, our focus in this was actually on the glazes because there was a very interesting material that was known as Böttger luster that was developed in the Meissen manufactory that was iridescent. And the interesting aspect of that is by something as simple as X-ray fluorescence, one could understand there was gold in that iridescent coating. This is not like a gold layering. It's an iridescent coating, more purple in color. And there were other purples in these glazes where you would just see color as derived from a pigment. And so, we were very curious, both a purple glaze and a purplish iridescent layer, both had gold in them. Why were they different? And so that really moved us in a direction to study those in great detail."

De Guire: "And so what have you been able to uncover or discover about that difference that drove that curiosity?"

Faber: "So one of the techniques that we used was, of course, scanning transmission electron microscopy. But also through that we were able to do the elemental study to figure out which of the elements of the periodic table were there, so we could identify where the gold was, what the shapes were of these gold nanoparticles, what the size distribution was.

So we started this work at Northwestern. Anikó Bezur went off in one direction, I went off in another direction. But I have a student here at Caltech, Celia Chari, who came here because she wanted to do some work on cultural heritage. And so I said, 'Okay, here's an unfinished problem.' We also found another talented undergraduate, Zane Taylor, who was willing to look at the optics part of it. Why should gold particles of one size or one size distribution produce an iridescence and not in another, just a purple pigment?

So we put all this together. Celia then even went further and recreated some of these materials. We knew historically that Böttger in the laboratory used some pretty unsafe methods to produce this gold. Some gold that they would basically ignite to get the gold to go into the glaze. We decided that was a little too risky for us in our lab, but Celia was able to do this with gold chloride. So, the work that was published included not only the difference between this Böttger luster and the purple glaze known as Purple of Cassius but also how this can be recreated today."

De Guire: "Interesting. You mentioned some of Johann Böttger's laboratory techniques. Do you have any sense of how much he understood about the chemistries that he was playing around with? Because it's pretty sophisticated."

Faber: "You're right, it is very sophisticated. Certainly they couldn't see these nanoparticles, they had no idea. The work done to be able to image colloidal particles came about in the early 20th century. But what they did know in the early 1700s was that there were certain chemicals that produced certain colors. In fact, there was an understanding of gold producing a reddish purplish color as early as the Greco-Roman era. But in terms of understanding this as a nanoscience or nanoengineering problem, Böttger did not know that. And I'm sure that much of this just happened through trial and error. At the same time, just in terms of the porcelain base, one of the things that they had figured out at Meissen was how to get higher and higher temperatures in kilns, and that was critical to making the porcelains and made it easier to make some high-temperature glazes as well."

De Guire: "Very interesting."

(music)

BREAK

De Guire: "The American Ceramic Society's Art, Archaeology & Conservation Science Division aims to advance the scientific understanding of materials found in ceramic art and to provide information that aids in the interpretation and preservation of traditional ceramic art and artifacts. Learn more about this Division at www.ceramics.org/aacs."

SECTION 3

De Guire: "You already talked a little bit about how your career in industry led to a Ph.D. and then to academia. But what is your approach as a professor and a mentor? And what are your goals as you work with students?"

Faber: "Well, I guess I would start by saying that, in terms of being an academic, there is no greater joy in all of this than to watch a student grow intellectually and grow in their curiosity and become the expert. And just to watch that happen is just an amazing thrill. And I realize how lucky and how privileged I am to be able to watch that growth. And so, with that in mind, that's how I think about mentoring. How can I give them enough guidance and enough information—that's not too much—because I want to see that growth. So, it's this delicate balance that you want to give them enough so that they can be the expert but that they get to that position of expert through their own initiative."

De Guire: "Ah. That's a pretty subtle thing to achieve."

Faber: "It is. I'm not sure I have had success in every instance because sometimes some people need a few more nudges than others."

De Guire: "Sure. That's all part of learning how it works and kind of owning your knowledge and your experience. I also wanted to talk to you a little bit about your experience with The American Ceramic Society. You're a past president, you're a Distinguished Life Member. So, obviously the Society's played an important role in your life, but how did you first hear about the Society? And how has it impacted your career?"

Faber: "So I became a member of The American Ceramic Society while I was at Alfred. So, during my undergraduate education. And I think it was expected, if you were going to get a degree in ceramic engineering, of course you would be a member of The American

Ceramic Society. And during my senior year, I had the opportunity to go to an annual meeting of The American Ceramic Society in Washington, D.C. And there were Alfred alums who were now in graduate school, who we saw at this meeting. To go to your first conference in a big city, it was quite an experience, and I said, 'I'm in. I want to continue this.' And I certainly have no regrets because through The American Ceramic Society, as I'm sure many people would say about their professional organizations, you form this network not only of friends, but because of your commonality in interest, they might also become collaborators over the years. And that has been a very, very valuable aspect of all of this."

De Guire: "Right. Have the same common interests, kind of want to achieve similar goals, all that. Great. How have you personally been involved in the Society? You didn't just wake up one day and become president. There was a process there. Can you talk a little bit about how you got involved and why?"

Faber: "So my very first faculty position was at The Ohio State University. So I was down the road from you, and the department chair at the time at Ohio State was Dennis Readey, who was very well involved in The American Ceramic Society. And I can remember him coming into my office and saying, 'Okay, you know they're putting the program together for the next annual meeting.' At the time it really was just up the road in terms of the location of the ACerS building. And he said, 'Come on, you can be a part of this.' And the next thing I knew, I was on the Program Committee and doing more and more, and then doing the program for the Basic Science Division, and it just continued. And once you're in the door, and you start contributing to the efforts, you are asked again and again. And it was a great learning experience to have to be able to have various leadership positions within ACerS."

De Guire: "Great. How would you suggest somebody new get involved in the Society?"

Faber: "Well, if they don't have a Dennis Readey, I think there are some wonderful opportunities to just volunteer. So, in annual meetings, in meetings of the various Divisions, there are often opportunities to sign up to be a part of a committee. And there are so many committees that have different purposes, [it] likely that you are able to find something that is in your bailiwick."

De Guire: "Right. In your bailiwick and also within your timeframe, the time you have available for that kind of activity. Great."

(music)

CONCLUSION

De Guire: "Though our tendency is to look always forward, sometimes taking the time to look back will provide us guidance to build an even better future.

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 Katherine Faber and her research. 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.”