CERAMIC TECH CHAT

Episode 51

Title – "Glass recycling challenges and solutions: Collin Wilkinson"

INTRO

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

Computer modeling and simulation methods are becoming integral tools in the push to expedite efficient development of new material systems. But as with any tool, these methods are easier to use with certain material classes than others."

Wilkinson: "I think glass has some unique challenges, which makes it fun to try to apply these techniques to glass. But by combining these techniques with the experiments, we've been able to extract even more precious information about the underlying chemistry and physics of these materials."

McDonald: "That's Collin Wilkinson, assistant professor of glass science and director of the Center for Glass Innovation at Alfred University in New York. Collin uses both modeling and experimentation to address sustainability challenges in the glass industry, with a focus on glass recycling.

In today's episode, he'll describe how he became interested in this topic and some of his current research projects, which you can learn about in more detail in the upcoming September 2024 issue of the *ACerS Bulletin*."

(music)

SECTION 1

Wilkinson: "So, when I started out, I was really set on being a physicist. As you know, we met at Coe College in the physics department once upon a time. And so over time, I really enjoyed the physics. But as I started to do physics internships, I realized that a lot of the problems they were having were actually materials problems. So, I became increasingly interested in materials. And at Coe College, of course, we have wonderful expertise in the form of Steve Feller and Caio Bragado and Mario Affatigato, and all of them together have this wonderful glass program there. And so, since I was interested in materials and glass was there, I really started slowly investing my time, learning more and more about glass until the point I was so hooked I couldn't turn back.

From there, I went ahead, and I met this really nice guy who gave a talk at Coe College my junior year. His name was John Mauro. And poor John. I kind of cornered him and asked a bunch of questions about materials modeling all at once. And the next year he announced he was at Penn State. So, me and my colleague from Coe College, Anthony DeCeanne, we both ended up going to join John's group. And ever since I've been well invested into the glass science community."

McDonald: "So, that sounds like a really fun pathway. It started with the physics, but then once you really realized that physics can be applied to materials in so many ways and kind of like, 'Hey, let's take that physics and make it an applied field.'"

Wilkinson: "For sure. It's one of the most interesting things, right? And the other thing I really liked about it is that it's very close to physics, but it has what I would consider much more immediate applications compared to many of my physics colleagues or my internships, which were, for example, on gravitational waves."

McDonald: "So you mentioned that one of the reasons you became so inspired and decided to pursue your graduate studies with John is because he came to Coe and gave a talk on modeling. So, let's talk a little bit about that. Did you have any experience with computers and modeling prior to that talk by John?"

Wilkinson: "Yeah. So, I've always been interested in Python. And then in my previous experience at Coe, I was writing some Monte Carlo codes for particle physics. I ended up spending a lot of time actually getting involved in the computerized solutions to physics problems. I thought that was like a really interesting problem.

And the other thing is, Lisa, I'm not that good at math. So being able to solve things with a computer was really, really helpful to me because I could write a code that would calculate the solution without me having to physically sit down and do the math. I still encourage students to do the math, and I still try to practice. But it was something that I became really interested in early on. And then when I started getting interested in glass, I found this really nice mix through John Mauro about how we're going to pursue this."

McDonald: "So when it comes to modeling, a lot of people have been hearing recently about machine learning, simulations. That's become a really big thing in the materials field right now, is using these types of computer systems to advance materials science more quickly. Why would you say that glass specifically is well poised to be analyzed and investigated with these techniques compared to other materials?"

Wilkinson: "That's a great question. I wouldn't say glass is particularly…the best technique for these things to be applied to because there are some unique challenges with glass. But these unique challenges are what makes it fun to try and figure out how to apply these techniques to glass.

For instance, if we look at ceramics, there's the wonderful materials project [Materials Genome Initiative]. They have precalculated the band gap, they precalculated the relaxed structure, they've precalculated the electronic density of states. All sorts of wonderful information already precalculated online for you to access.

With glass, it's a little bit more complicated because it's nonequilibrium, right? We don't know the exact structure of atoms. We don't know exactly what the energy should be because of this complex problem associated with quench rates and with the nonequilibrium processes of glasses. And so those complications add in extra flavor or extra interesting aspects that we try to draw from and try to solve those so that we can use these tools in the future for engineering."

McDonald: "Can you tell us briefly about some of the main techniques that you use. How they work, and what science problems that they're used to answer."

Wilkinson: "In our group, we're kind of interested in the different scales of glass. On the smallest scale, we have these kind of atom–atom interactions. And it turns out to be good at modeling materials, you really have to describe the energy of interaction somehow.

And so, on the smallest scale, we're using what's called density functional theory. Density functional theory is ab initio, which is just a fancy word for saying from first principles. It's based on using quantum mechanics to solve for the properties of the material. And that's really great, right? Because you can put in a structure, you figure out where the electrons are, you can get all sorts of wonderful information from this.

The problem with that, of course, is that it's hard. Quantum mechanics is not easy. So, for glasses, we need quite a big number of atoms, maybe a couple hundred atoms to even start to represent a glass. And that's just not feasible for a lot of quantum mechanical codes. So even though quantum mechanics kind of gives us the origin, the most accurate measurements of energy, we can't directly apply it to glass.

So often we move up to the next scale, and the next scale is molecular dynamics. And molecular dynamics is a wonderful technique. It's my personal favorite technique, not that we have favorites. But the idea here with molecular dynamics is that by simply knowing the energy between atoms, you can calculate the force acting on each atom. And if you can control the temperature, you can start to make direct observations of the properties. And so this is a very simple idea, but when you apply it correctly, you can get all sorts of wonderful insights.

The challenge with molecular dynamics often is that when you're measuring the forces on an atom, watching how they move, you have to do it with a very small amount of time. So usually we are not observing atoms move for longer than a microsecond. So, that means all of our quenches, all of our properties have to be calculated within a microsecond. Much too short.

So, my group now is really focused on how do we take these kind of classical approaches and extend the time so that we can start to look at longer properties. Or, how do we use things we know about the system to calculate physical properties, like heat capacity, like viscosity, like other things that we know we can't directly observe in molecular dynamics."

McDonald: “That is really interesting. You explain that so well at each of the different levels. Very small, as it starts getting into larger scales, there’s so many different layers to materials that you have to consider [that] give it the properties that it has.”

Wilkinson: “For sure. You know, that’s one of the wonderful things, right? Especially as you get into ceramics or like glass-ceramics or any sorts of ceramics, it’s not just atom–atom interactions and not just large larger atomic interactions like we see in MD [molecular dynamics], but then we get to the grain scale and from there we can go to parts scale. So, this continuum, it’s all a challenge for us to model. But working towards this can help us really work towards rigorous physical design of materials.”

(music)

SECTION 2

McDonald: “Of course, learning about these properties for information’s sake is very fascinating, but a lot of times we’re specifically looking to understand these properties so the glasses can be used better in application. And I know specifically in your case, you’ve been very interested in the environmental friendliness design of glasses because glasses can be very energy intensive to create.”

Wilkinson: “Yeah. So, the first time I took a real materials class was in graduate school. I remember very clearly sitting in doctor Susan Trolier-McKinstry’s class and being like, ‘Oh, wow, there’s a lot here.’ Like being really impressed and excited about learning materials.

But at the end, one thing that I found was that I had not really learned about the environmental impact of what we were doing. And it turns out if you go and look up the environmental impact by sector, materials is not a negligible effect. Cements and steels are two of the most to the largest anthropogenic origins of carbon emissions.

So, as I was leaving school, I was really interested in this problem of how do we actually create something that’s more sustainable, how do we actually deal with these anthropogenic emissions. I’m going to keep repeating anthropogenic because it’s one of my favorite words.”

McDonald: “And you have practice saying it, don’t you?”

Wilkinson: “Yeah, many times. So, I was really interested in this like understanding how and why do we balance and design better materials for the future. Of course, when I was at Penn State, doctor Mauro had already started noodling the idea of LionGlass, which has since become a huge idea, and it’s awesome work coming out of Penn State. But when I left, I was really interested in recycling because it seemed to me if we think about it, the carbon emissions of glass come from two main sources. The main source is heating the glass and then the CO_2 coming off of the carbonates.

So when we make glass, we calcine calcium carbonate, sodium carbonate, silica. Those are the three basic ingredients for soda lime silicate. And then most of those are giving off CO_2. And at the same time, we're heating the whole thing usually with natural gas.

And so it turns out the most environmentally friendly thing we can do today, in today's furnaces, is add some recycled glass. By adding 10% recycle glass, you can see a 3 to 5% reduction in energy cost depending on who you ask. And that is a huge deal. But if you go to speak to the people at factories, they have a terrible time getting cullet. They have a terrible time like getting this glass, which is overwhelmingly going to a landfill.

And so, this became a really big interest of mine immediately because like you would think in your head, right, all this glass can help us save energy. The factories want it, people want it to be recycled. And yet overwhelmingly here in New York, about 50% of the glass goes to landfill."

McDonald: "That is just insane. Especially when you think about Europe, you know, we hear about the rates coming out of Europe, they can reach 80 plus percent recycling. But it seems that we've struggled in some ways to mimic those systems over here in the United States."

Wilkinson: "I think that's true to a degree. I think there are advantages Europe has. So, for instance, New York state used to have a lot more glass factories than we have today. And that's not a problem with the glass factories because what has happened is the number of glass factors have shrank and the factories that exist have grown substantially. And that has led to cheaper glass, that has led to more availability of glass. That is an all-around positive thing. But as that factory exchange happens, the distance you have to transport the average waste glass significantly increases. Our shipping costs are really high in the United States. We have a long way to ship.

And then the other thing is here in the United States, we don't really have an alternative sink. Something else where we can put recycled glass to turn it into a good product. If we look in some of the Nordic countries, there's foam glass, which is a really nice idea. You can take some waste glass, mix it with a little bit of a carbonate, and then fire it through a much lower temperature kiln. And what you get is you get a really nice foam that you can then break up and turn into roadbed or soil amendment or something. And though that's not exactly the highest tech application, it is still a use for waste glass that we don't have here. The only real applications we have for waste glass is remelting in container factories and remelting in fiberglass companies."

McDonald: "I assume, you know, even though a lot of the ways we can reuse glasses by putting it back into other glass products, that's probably not possible in all cases, correct?"

Wilkinson: "That's true. That is a real challenge. As you can imagine, if you're a factory, you have really tight specs on what you want to put in your furnace. Your furnace is your biggest asset, and putting in glass that's dirty, that's really fine, these all create problems that can impact the life at the furnace or impact the quality of the glass. And so when you're a manufacturer, you're actually pretty hesitant. You really have a tight spec that your waste glass has to reach.

Unfortunately, in recent years, there's been more of a lockdown on color, so colored glass is becoming more difficult to recycle. But these are these are not unreasonable things from manufacturer point of view. If you and I had a tens of millions of dollars furnace as well, we wouldn't want to just put anything in. So, it becomes a challenge in how do we get the quality of glass as well.

Something that I like to say is that like most glass can be transformed into high-quality cullet that can go into a furnace. The only stuff that really can't is fine stuff that is too small to go into a furnace. But the problem is that the cost of that equipment, the cost of shipping it to a place that can do that equipment, and then shipping it out again is really, really high. And so it becomes this balance of how much do we need the glass, how much money will it save versus how much are we building to spend to get it."

McDonald: "So, where would you say are maybe some of the most promising avenues for glasses that it's too expensive or infeasible to turn back into glass products? What are other streams or other types of products they could be used for?"

Wilkinson: "This is definitely a challenge, let me start with that way. I'm personally pretty optimistic about foam glass in the United Sates. Foam glass is that material where we're mixing that carbonates that 1 or 2% carbonates with the waste glass and then firing it in a kiln so we get a glass structure that is mostly porous.

If we look at the foam glass producers in the United States, we can look at Aero Aggregates, which is in Philadelphia. They take a lot of the terrible dirty glass that can't go anywhere else from that kind of eastern Pennsylvania region, and they turn it into roadbed. Sorry, they prefer the term geotechnical fill, slightly different than roadbed, I apologize. So, AeroAggregates is, you know, taking a lot of glass, turning it into a product that we need, right? The foam is lightweight, so it's cheaper to ship. As far as I can tell, that one factory is producing much of what we need on the East Coast.

While we're here, AeroAggregates has done a great job recently. They were involved in the cleanup of the Philadelphia mess. There was a truck that caught fire that caused a bridge to collapse outside of Philadelphia, and AeroAggregates then donated the material to quickly rebuild the bridge and provided the new infrastructure needed so that the traffic around Philadelphia did not end up getting blocked. So, there's a great photo of Joe Biden with some foam glass."

(music)

BREAK

McDonald: "ACerS' four journals are filled with cutting-edge research on methods and materials to enhance the sustainability of ceramic and glass production and use. To recognize this important work, the ACerS journals team curated several special Topical Collections this year on various aspects of sustainability. View and read the articles in these sustainability-focused Topical Collections by visiting bitly.com/ACerSTopicalCollections."

SECTION 3

McDonald: "So, you've given us a very nice broad perspective of some of these different challenges and considerations that must go into the recycling and reuse of glass. Can you tell us some more about your personal journey and the places that you've worked and what specific projects you've done in this area."

Wilkinson: "Yeah. So, before I became faculty here at Alfred University, I was involved in a foam glass company. So, I am biased. We were trying to make them functional by adding more things to them. Instead of just considering a carbonate in glass, we were saying, 'Well, let's tune the glass chemistry as well. Maybe we'll add some boron, make it a borosilicate, and try to make the advanced version of foam glass or foam ceramics.' Eventually we turned them into glass-ceramics, but that's a story for a different day.

We were shooting for a couple different and applications. So, if you control the chemistry really well, you can get open cell foam. So we were trying to make some like filter media for high-volume filtering. We were also looking at construction. Construction is something that we've really stuck into. And the reason that foam glass is really nice for construction is because you can keep the compressive strength really high, and it's lightweight. So if you put it into some concrete, you can really make some nice materials that are lightweight but retain their strength.

The challenge there is what is called alkali silicate reaction. And that happens when the alkali in the glass escapes and gets into the cement and causes some bonds to break down. And that can actually cause long-term deleterious effects to the concrete. ASR is often called concrete cancer. So, we were looking at different ways of mitigating that, of trying to control that.

And then after the startup, I went back to Penn State for a very short amount of time. Thank you, John Mauro, for hosting me once again. And then I came here. And since I've been here, my group has really split 50/50 between trying to understand modeling and the physics of modeling but also trying to really do some sustainability work. So, we have a couple projects that we're working on that I'm really excited.

One of those projects is with my student, his name is Aiden LaCourse. I think you're going to be speaking to Bill LaCourse soon, this is his nephew. Aiden currently is at an internship at SpaceX, but Aiden was doing some really excellent work on trying to understand the different effects of ASR and how we can mitigate it. And through Aiden's work, we were actually able to develop a 3D-printable glass concrete mix that is now being used to print buildings, or it will soon be used to print buildings, with SQ4D, a home printing company in Long Island.

Another really great, exciting piece that I'm working on is solar panel recycling. So, if you could imagine, solar panels cost a lot of money to put them together. And currently solar panel recycling consists of stripping off the aluminum frame, taking the junction box, recycling those, and then throwing away the glass and the silicon because it's too expensive, too inefficient to separate. So recently we've been really trying to develop methods to be able to recycle these solar panels with much higher efficiency."

McDonald: "Is there some overlap, then, kind of between those two groups you have? The modeling and the sustainability?"

Wilkinson: "Of course. So, a lot of the challenges that face recycling are materials challenges, right? You know, if you, for instance, consider solar panel recycling. You could recycle solar panels if you could delaminate or detemper the glass before the EVA, the polymer holding it all together, starts burning. So, if you could relax that glass without burning out the EVA, you could much more efficiently recycle solar panels. Glass relaxation, polymer decomposition, present various materials challenges. Same with the use of glass in construction materials. You have to overcome these ASR challenges.

As you can overcome these ASR challenges, which, by the way, are fundamental chemical reactions that are described by Arrhenius expressions and by forward rate diffusion approximations, you can also start to describe what materials will work in construction, which materials don't.

So ultimately, we are always trying to return back to the fundamental physics, but the applications we're looking at now are largely sustainability."

McDonald: "So, it all really is like a giant circle. It comes back together again."

Wilkinson: "You know, I don't really have any new ideas, Lisa. I just keep doing the same thing over and over again."

McDonald: "But you've been getting some really great results. Sometimes perseverance and knowing what works is the best pathway."

Wilkinson: "That's exactly right. And, you know, having good students also helps with that. It's important to note that I don't actually do anything. I just have this circular idea that I keep pushing on my students, and my students keep doing it."

McDonald: "Well, I mean, isn't that the essence of sustainability? The circular economy?"

Wilkinson: "Exactly right. You know, we're thinking the right way."

McDonald: "Gotta think in circles. So, do you have a specific research project that maybe you're most proud of? Or like a result that you have that you really feel is going to make a difference in this world that you're excited that you were able to help lead the charge?"

Wilkinson: "I do. Like around some of the glass modeling work, around some energy landscapes stuff that I've done. But actually the thing that I've been really focused on recently that I've been most proud of is working with my undergraduates.

Coming from Coe, you and I, we both did undergraduate research, and I found that experience very formative. And now, myself and others, like Myungkoo Kang and Ben Moulton and Rebecca Welch and Scott Misture, all of these people are contributing to this undergraduate research program. And what we found is that we've been able to grow our program quite a bit since I've been here. We went from having only a handful of students every summer to having over 30 undergrads per summer working in our labs.

And so I think watching students grow is the thing that I've been most excited about recently. Especially I recently took one of my students, Wyatt Kiff, to the U.K. This was last summer, I took him to the U.K. And it was clear to me that that experience was very formative to him. He's now at PNL [Pacific Northwest National Laboratory] now, he'll be back in a couple weeks. But he's really grown a lot by engaging in undergraduate research, and him and others are really the things that I like to see the most."

McDonald: "That really is fantastic because, you know, undergraduate research isn't necessarily that widespread. Like we had that fortunate experience that Coe College, you've now been helping to build up this Summer Research Institute at Alfred. What have you seen, I guess, are the biggest benefits of introducing students to research at that younger age versus maybe for the first time when they get to grad school?"

Wilkinson: "Yeah, that's a great question. So, the first thing you should know if you would like to start an undergraduate research program is that you're not gonna, like, the ROI from a like papers published standpoint, from like research done standpoint, not necessarily there. And that's okay. But from like an impact standpoint, it's really high because it's very clear that students who engage in the program are very quickly learning whether a) they wanna do science or not. And if they do, they realize really quickly what it's like. And so for many of them, you can watch them grow in the course of a summer more than you've seen them grow in like two years.

And so, giving them the opportunity to learn really gives them the opportunity to figure out if they a) want to go to grad school, if they're willing to put in that work. And then also, the students who do do that work realize very quickly, 'Okay, this is what grad school is going to be like. Probably even more intense than this. So, I need to understand, I need to decide that this is what I want.' And so those students who go on to decide to go to grad school, I don't have that much data yet, but I believe, I hypothesize that they will do better in graduate school.

The other thing I have to say is like Alfred University is very unique in its ability to do this. We don't have so many graduate students right now, but we have a ton of equipment. So having the ability for undergraduates to engage in this program is very formative and useful to us as faculty to get data and to like have some work, have some things that we could turn into papers, as well as for the students. It's not just a one-way deal."

McDonald: "That is wonderful."

Wilkinson: "Oh, I should also shout out Steve Feller, who developed the Coe College one, who I am blatantly ripping off here at Alfred University to try to develop our own undergraduate research program."

McDonald: "People who are long time listeners of our podcast probably remember when Doc Feller was one of our guests a little bit while ago. And I'm sure he'd be thrilled to know that he inspired his student in such a way to go on and establish his own research program.

And I'm also really excited because, you know, we've just briefly touched on some of these topics today, but you're actually going to be contributing our cover story for the September *Bulletin*, which will be coming out in just a couple of weeks. And so all of our listeners who'd like to learn even more details about some of these topics can check out the *Bulletin* and read about them in there."

(music)

CONCLUSION

McDonald: "Improving glass recycling rates in the United States is an important but complicated task. Fortunately, through the work of dedicated glass researchers such as Collin, the outlook for reducing glass waste here and around the world is very bright."

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 Collin Wilkinson and the research taking place at Alfred University's Center for Glass Innovation. 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."