**CERAMIC TECH CHAT**

Episode 58

Title – “Transitioning niche research to market: Joe Cesarano”

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INTRO

McDonald: “I’m Lisa McDonald, and this is Ceramic Tech Chat.

Additive manufacturing is a processing method that involves building 3D objects one layer at a time. Similarly, entrepreneurs working to launch their own company often start with a single core idea, and gaining more knowledge and experience step by step allows them to grow into a successful enterprise.”

Cesarano: “You know, there’s such a vast number of topics for ceramics. You can’t possibly know them all. So, to be a member of the Ceramic Society and also to learn about this different stuff, even if it’s just on a very low level, is really interesting. And then sometimes, you get stuff that really ties into what you’re doing. And sometimes, like in our case, it turns into collaborations.”

McDonald: “That’s Joe Cesarano, founder and president of Robocasting Enterprises. The company uses a 3D printing method called robocasting to build different types of ceramic components. The method began as a research project at Sandia National Laboratories, and Joe successfully transitioned that research into commercial application through his company, which now has more than a dozen employees.

In today’s episode, Joe will explain how robocasting was developed, provide examples of its applications, and share tips on how to successfully bring your ideas to market.”

(music)

SECTION 1

McDonald: “So, how is it that you became interested and involved in this world of ceramics? Did it start from a general love of science that then you found this subdivision? Walk us through when did you become interested and end up in this field.”

Cesarano: “I knew I wanted to be an engineer. So this was, I graduated high school in 1979. So, think of the era. There was this new field coming out, and I always loved to build things. I always loved to, you know, work on puzzles. I was an engineer from when I was a kid. I knew that. But there was this new field coming out called computer engineering. So, that’s what I tried to do, and actually got accepted at Clarkson University. And went there to visit a friend of mine during our spring break of senior year. The program was fantastic, but I was there for like three or four days, and at the time—remember the era—there was probably about maximum of ten girls on the entire campus. And I'm sorry, I can't do this.

At the last minute, it's April, my senior year, I'm looking for other places to go. And the Alfred University basketball coach was interested in having me play basketball there. So, I went down and did a visit, and the only engineering they had was ceramic engineering. That was it. I knew nothing about it. Never even heard of it. But with the tour and talking to grad students and the professors. At the time, the big thing of the future was going to be ceramic car engines, and that intrigued me. It just was a whole new world that I'd never heard of, and it was very hands-on, and I bought in. And they were able to get me in even though it was such last minute, the basketball coach actually was able to get me accepted."

McDonald: "So, once you got to Alfred, did you do any research in ceramics during your undergraduate studies there?"

Cesarano: "I was playing sports, and there really wasn't time to sort of do that. But senior year, we had a thesis project and got into research that way."

McDonald: "And so, after you finished your undergraduate studies at Alfred, where did you go from there?"

Cesarano: "There was a program from Sandia National Labs that was looking for kids that were graduating from B.S. and then were planning to go to grad school. And the idea was to just have them work for the summer at Sandia. The recruiter for that was a former, his name was Bob Eagan, was a former Alfred alum. And there were three or four of us that wanted to go to grad school, and he hired us for the summer.

So, that summer, I got to go to Sandia Labs and really get into what research was really like. And then I started grad school at the University of Washington in Seattle that fall. Got my master's there in, they still had ceramic engineering—you know, back then, several schools had the program—and then got my Ph.D. in materials science from the University of Washington. Then, after that, stayed in contact with the Sandia folks and ended up getting a job there afterwards. So, I've sort of been in Albuquerque [New Mexico] ever since."

McDonald: "Once you got to Sandia, what type of work did you do at Sandia?"

Cesarano: "So, a lot of my graduate research was primarily all in ceramic processing. And it's interesting. It was called colloidal science. So, the studying of small particles and how they interact and then relating that to how we could process a ceramic. It irks me a little bit that colloidal science was this thing, and then someone in the '90s changed the name to nanotechnology, but it's the exact same thing. So, basically, I was working on nanotechnology for my research and how it related to making ceramics. That's exactly what I did in grad school and then continued that at Sandia as well."

McDonald: “So, I know now you are founder and president of what is called Robocasting Enterprises, and the specific type of 3D printing that you do is called robocasting. Can you tell us a little bit how it differs from some of these other slurry-based techniques we might know about?”

Cesarano: “Absolutely, I’d love to tell you about that. So, it’s starting with a slurry, or I’ll call it a paste because you have to get the rheology right for the process to work. But let’s call it slurry-based processing. Having it work isn’t like an FDM process or a process where you have a filament, where you have a wax or a polymer that’s filled with ceramic particles. In that case, the feedstock is liquefied by heat, and then once it’s cooled down, it solidifies and sort of cures. And now you got to get rid of all of that wax or polymer before you can get the ceramic to sinter.

So, our approach was to eliminate that and start with a slurry that is the carrier. Now [the carrier] it’s not a wax or thermoplastic material. The carrier is a volatile solvent and, hopefully, water, most of the time. And then the quote curing occurs because when you remove a little bit of the solvent, the rheology transitions from a suit of plastic, shear-thinning state, into like a dilatant state. So, the part is still wet, but the viscosity and yield stress are very high, and it can support itself while you’re building. Then afterwards, you have to dry the part completely and then sinter it.

So, that’s the unique feature of this, is that it’s this slurry base with the feedstock being carried by a volatile solvent. That’s in essence what robocasting is.”

McDonald: “So, with this robocasting technique, can you give us some examples of things that it does really well, and then alternatively, maybe some things that it doesn’t do quite as well.”

Cesarano: “So, imagine what it is. Like I said, it’s a paste being extruded out of a fine tip. So, it’s almost like automated cake icing. You’re drawing a 2D pattern, then you come up with this paste, like toothpaste, and you do another layer by layer. And because of that, it’s a very fast 3D printing technique compared to the other techniques. So, we can literally print parts in minutes; really big parts in just a couple of hours. And then you can process the part, for small parts, in less than 24 hours. You don’t have to worry about excessive binder burnout and all that. So, it’s fast.

But you are putting down these layers that are relatively thick compared to other techniques. So, it’s really good for making parts that don’t have to have super high precision and can accommodate the uncertainties in sintering ceramics. Because we have to build in the shrinkage factor to the original design, right? And how they shrink and whether they warp and all of that has now all the typical ceramic processing problems you have to deal with.

So, from that regard, it’s things that can benefit by being made quickly and where the geometry that we build has some sort of performance value but not necessarily the dimensional tolerance.

Oh, the other thing about robocasting that I guess I didn't specify is that because we're starting with fine particles and we're using that as the basis for our feedstock, we can print hundreds of materials. We just have to get the particle size right, and particle size distribution plays a role as well. But once we understand the surface chemistry, we can work a lot of different things. So, we're not limited by the optical properties like for the light-based, stereolithography techniques or…

Anyway, several of the techniques, you can work with five or ten different materials maybe. But to be able to work with just hundreds of different materials and mixes of materials and being able to have multiple feedstocks that then can transition from like ceramic to metal all in one operation, that's the versatility of robocasting is different. Again, with the caveat that, or with the limitation that we're not necessarily great at really small, high-precise parts. So, those other techniques are probably better for that."

(music)

SECTION 2

McDonald: "Robocasting Enterprises is an outgrowth of what you did at Sandia, correct?"

Cesarano: "That is correct. In the mid '90s, all of a sudden that's when 3D, well, they didn't call it 3D printing, free form fabrication became a thing. There were techniques flourishing, really being developed pretty quickly for plastics and for metals. But there wasn't really much going on with ceramics, and especially not with a slurry-based process.

So, I got some internal funding from Sandia. They were interested in trying to, 'Okay, let's see if we can do free form fabrication with ceramics as well." And so I got a project to start working on that, and that's where we developed the first approaches to doing this free form fabrication or 3D printing using a ceramic slurry or ceramic paste as the feedstock and then putting it down layer by layer.

So, when we first started the free form fabrication, what later became robocasting, I was working on aqueous injection molding and a way to take a slurry that is now a fluid and turn it into something that has a shape. That was the feedstock we were working with. So, we actually had extruders that were heated, and then it would go through the extrusion process and be cooled as it was printing.

We were trying to do that, but it was complicated, and it was hard to get the timing and all the kinetics just right. Because the way we made the feedstocks is we would mill a slurry, just have it sitting there in milling, and then we would add the gelling agent when we were ready to go with further processing.

So, we had this slurry sitting on a roller and we had lost track of it. And about three weeks later we realized, 'Hey, this thing's still on a roller. This thing needs to, we need to do something with this.' And [we] opened it up, and it had like the perfect rheology for robocasting: a nice sheer thinning, and it was high solids loading. And said, 'Well, let's just try this as is,' and tried it and it worked. And so then it led into, 'Okay, how did it get to that point and what's going on in there?' and doing some science behind it. But if I hadn't gotten lazy and let it sit around for three weeks, I probably would have never noticed that the aging process gave us a perfect starting point.

So, we created it there, got patents on it, and it was a really cool technology. So we started to try to find companies to license the technology and, you know, have the big guys come in. And everyone who saw it thought, 'Wow, this is really cool,' but nobody could see a market for it; it was just too far before its time. If there wasn't like at least a $100 million market, it's not enticing for them to try to take it to the next level from such a low TRL [technology readiness level], from such a beginning state of the research.

So, with that, we kept plodding along, and we started using it to do lots of different things, multiple materials and bone scaffolding, and we proved that it could be used for lots of different things. But again, there just wasn't this market. So, after about five or six years of this, Sandia was going to have me start working on other things because there wasn't an internal use for the technology at the time. And I just had too much of my heart and soul into it to let it be shelved. So, yes, there wasn't a $100 million market, but we were able to find one niche where we thought we could commercialize it and decided to spin it off from Sandia and turn it into a small company. And that's where we've been ever since. So, that happened in 2007."

McDonald: "That's a really great story, that even if it's not necessarily going to have a widespread impact, if it can have a deep impact in a certain niche area, that can make all of this research so important and worth the while. Not everything has to have widespread impact to be important."

Cesarano: "Yeah, exactly. And now, 20 years later, I mean it is being used all over the world for different things."

McDonald: "Can you give us some examples of what types of products is it really good at creating?"

Cesarano: "What we found, what is the foundation of the company, is that when we get the rheology of the paste right, we can make these lattice structures, like Lincoln Log structures. It turns out these lattices, especially when we build them in such a way that they offset and there's a tortuous path to flow through them, turns out to be super efficient for removing impurities from molten metals. So, they work really, really well for investment casting of super alloys for the aerospace industry. That's our little niche for the company.

The other half of the company does R&D and using the technology to do all sorts of really kind of cool stuff where again that criteria remain, that the geometry that we build and the shapes that we build provide some benefit or performance value."

McDonald: “So, what other application fields in general have you worked with for this R&D?”

Cesarano: “Well, one of the real exciting areas are for high-temperature heat exchangers. So, for heat exchangers to work in really extreme environments, so where you couldn’t use metals. So, they’re envisioning like on the back end of a gas turbine. Can we collect a whole bunch of that heat, really high heat, and use it for some other purpose?

So, the project we worked on for ARPA–E was to create a ceramic heat exchanger that could operate at 1,100°C and using supercritical $CO_2$ as the working fluid going through it, and at high pressure. So, you know, very tough boundary conditions. And we were able to do it by robocasting silicon carbide to very high density, to like 98% density, and creating internal channels and stress relief geometries in this structure. We haven’t tested it at 1,100°C yet, but we have had testing up to 800°C. And they’re hermetic, and they’re working really well.

So, that’s kind of an area that is a little bit before its time as well, but hopefully the demand catches up with it. And we might be able to use it, or use similar type products using the same concepts, maybe for heat recovery in these big computer, the data centers, yeah, the data centers, where there’s going to be so much heat generated. Maybe there’s something we can do. And in that case, it’s not that you couldn’t use metals, but by using a ceramic, you don’t have to worry about RF [radio frequency] interference and electrical problems.”

McDonald: “I think those are really key points. And I also really like that fact that you mentioned you were processing silicon carbide. We usually think of things like the carbides as very difficult-to-process materials because they’re so hard and chemically resistant and thermally resistant. So this technology, or this processing method with the robocasting, probably provides an easier way of processing this very difficult-to-process material for certain applications then.”

Cesarano: “I would argue with you that it’s easy.”

McDonald: “Easier, I should say.”

Cesarano: “No, that was a big challenge, and we’re really excited that we’ve been able to do that. With a 3D printing process, we’re getting properties—thermal and mechanical properties—similar to traditional processing techniques for the silicon carbide. That’s pretty exciting.”

McDonald: “That’s very exciting. So, with all of this experience that you’ve had working with different industries, it makes you perfectly positioned for the next topic that we’re going to talk about, which is the ACerS Industry Task Force.

So, the Industry Task Force kind of evolved from the strategic plan that ACerS just did. We set up a strategic plan, and part of that was to better serve industry. So, this Industry

Task Force, then, is part of that strategic plan that the Society has to better serve industry in the future."

Cesarano: "That's exactly right. So, I'm on the ACerS Board, and one of the tasks that Monica, the president, gave me was to head up this task force to try to see if there's anything the Society can do to help with workforce development for the future and also if there's anything that we potentially can do to make the meetings more valuable to industry. So, we put out these surveys, and we've actually had a pretty impressive response. We've had like over 100 responses and probably over 65 different companies represented, and from different countries as well. So, it's a good cross section, and we're going through all the data right now, and we don't have conclusions made.

One of the things that I want to try to figure out is if we should really start lobbying more schools to have ceramic engineering degrees again. In the olden days, there used to be like fourteen or fifteen different universities that had specific ceramic engineering programs and degrees. And that's been diluted into materials science for the most part, with the idea being that a student would come out with more breadth and maybe be able to interact better in teams or to be able to interact in more global ways. And we're trying to get a feel for is that working for industry.

You know, the ceramic industry right now is loaded with guys like me that are either ready to retire or actually should have already retired. And so there's potential for a big brain drain in the next ten years. And so we got to start thinking about this problem.

And the other thing that's coming out of the task force that's really enlightening is that a lot of the companies are very interested in getting ceramic technicians. And so, there used to be two-year programs for that, and there aren't anymore. And maybe that's another thing that could be reinstituted.

So, we're trying to, we're talking directly with industry as much as we can to try to get feedback and see if we can make the Society as beneficial as we can to the ceramic industry in addition to academia and the national labs. They already have a pretty strong foothold for the meetings and for the population. So, we're trying to see if we can now bring industry back into that in the best way possible."

(music)

BREAK

McDonald: "The American Ceramic Society Corporate Partnership program serves companies of all sizes that wish to grow their business and support their industry. Companies gain access to ACerS' global network of ceramics and glass professionals, our publishing and professional development resources, and the Career Center for recruiting talent. Learn more about the benefits of ACerS Corporate Partnership by visiting www.ceramics.org/corporate."

SECTION 3

McDonald: "So, what advice would you give to students who are interested about maybe starting a company based on research that they've developed themselves?"

Cesarano: "Here's sort of what I've learned. If you're an engineer with an entrepreneurial ambition, the technology must be solid and have real value. That's a given. But the technology is maybe 10 to 20 percent of the likelihood that the business is going to succeed. Once you get into this, you're going to start being told you need a lawyer, you need a marketing person, you need all this different stuff. In reality, if you have the passion and you have the diligence, you can learn all the business stuff you need to to get started. Now if you start growing pretty big, then yeah, you have to hire experts. But don't be intimidated by that off the bat.

And the one thing that I learned is within like a year, you will know relatively quickly if you have something that's valuable or not. If you have something that's valuable, I like to say the vultures will be circling. The larger companies and people will be hounding you and trying to learn everything that you've got and trying to do everything they can to either collaborate with you or to usurp you and do the things on their own. So, if you feel that pressure, then you know you've got something. You know you're going to have some battles ahead of you, but you know you've got something. If nobody cares, if nobody is asking any questions, you probably don't have anything.

So, these things are difficult, but it still can be very, very rewarding. And I tell everyone even if we ultimately fail, I'm still really glad that I tried and took this path. So, that's a long way of saying that it's not easy, but it can be really worth it if you have the right personality, and you have the passion. So, go for it."

McDonald: "So, I think we've hit every single question that was on my list originally. But can you tell us a little bit how that name 'robocasting' was come up with?"

Cesarano: "So, as we were developing it at Sandia, we were trying to come up with an acronym, you know, a sexy acronym."

McDonald: "Well, you're in government. Of course you have to have an acronym."

Cesarano: "Exactly, right? But this [robocasting] is an offshoot of ceramic processing in general. You know, we have slip casting. So, slip casting is a process that can be used for lots of different materials, but people relate it back to the ceramics community, right? And gel casting is another one; tape casting is another one; freeze casting; vibratory casting. So, there's sort of this history where a processing technique that came out of the ceramics community was termed with a 'casting' suffix.

And one of the students—and this was at the time when robotics was just really starting to flourish, and RoboCop was a popular movie—and one of the students said, 'Let's call it robocasting.' And as soon as he said it, I'm like, 'That's it, that's what it's got to be.'

Because it's associated with all this great work that had been done in the '80s from fantastic ceramic processing pioneers. You know, my advisor, İlhan Aksay, and Mark Janney and Fred Lange. I mean, there was just a host of really, really great colloidal science related to ceramic processing that was going on in the late '80s and early '90s, and so it was natural to call it 'robocasting' and to sort of give this tradition. And I purposefully never trademarked the name because I wanted it to be associated with the ceramics community. And so, that's why it's called that.

Now, since then, the name has been changed, which frustrates me to no end. A lot of researchers will use it but then change the name, and I don't understand why that's the case. But that's the state of affairs. And so because as a company we don't publish as much, the name 'robocasting' has sort of got diminished, and now everyone calls it 'direct ink write' or 'microextrusion' or 'CODE.' There's a whole variety of things that people have called it.

But I'm trying, I'm really fighting, I'm trying to get on my soap box whenever I give a presentation and say, 'Look, we want this to be associated with the ceramics community. Let's call it robocasting. I don't care if you don't like the name. Direct ink write has no connotation to the ceramics world, and robocasting sort of does.' That's my little mission in life."

McDonald: "And who doesn't want to use a name that was inspired by a movie? That's just so much fun. More people need to just appreciate where the name came from. Then it's going to get an uptick in usage."

Cesarano: "I hope so."

(music)

CONCLUSION

McDonald: "Research can be a frustrating process at times, but with perseverance, passion, and a little bit of luck, it can also be a truly rewarding endeavor.

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 Joe Cesarano and Robocasting Enterprises. 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."