SMARTECH MARKETS PUBLISHING

Ceramics in 3D Printing Processes

A SMARTECH PUBLISHING Q&A

RECORDED AUGUST 2017

A Q&A Session with Davide Sher, SmarTech Publishing's European Director of Operations.

He is interviewed by Lawrence Gasman.

Lawrence: Good morning, this is Lawrence Gasman, president of SmarTech Publishing. We are the leading industry analysis and forecasting company in the 3D printing and additive manufacturing space. We're going to be talking about a new report that we brought out last week, covering the market opportunities for 3D-printed ceramics, including detailed market forecasts, analysis, and profiles of leading companies. The report is Ceramics Additive Manufacturing for Production Parts: An Opportunity Analysis and Ten-Year Forecast.

Today we are hosting a Q&A session with Davide Sher, who is our European Director of Operations based in Milan, Italy. Davide wrote the report we are discussing today and will be answering the questions.

Davide, could we lead off with you telling us a little bit about the key drivers for ceramics in the context of 3D printing, why is this happening, why is it happening now, so that we can get an overview of where has this come from and perhaps where it's headed?

Davide: Well, the thing about ceramics is that it's such a wide range of materials. You asked, why it is happening now? Now is a particular time for ceramics additive manufacturing because it's a newer technology for 3D printing—a newer material for 3D printing. So, the potential is enormous.

There are some clear advantages of 3D printing for ceramics. We're going to go see each specific process and each specific material. But, one of the issues is that, first of all, the printing speed is not a major factor because all ceramics has to be fired. Even for traditional ceramics manufacturing, and the firing takes a long time as well. So, speed is a relative element. Sometimes it's a limiting factor for other materials.

The other great thing, I don't think we're going to be able to cover them all, is that it's very difficult to work ceramics, especially the more technical ceramics, which are harder. It's very hard to work them into very complex geometry, which is exactly what 3D printing does best. Also, with 3D printing, you can avoid sub-assemblies. So, you can create

2025 Library Avenue Suite 402
Crozet, VA 22932
http://www.smartechpublishing.com

more complex parts that would require more different parts to be assembled. In 3D printing, you can do it as one piece, which is particularly beneficial to ceramic parts. Obviously, no tools are required. The fact that you can do on-demand manufacturing is an advantage of all 3D printing in general.

Sometimes in 3D printing you use materials that are only good for prototyping. But with ceramics, you get end-use materials, so, you could do already production if you wanted to. There are so many applications that 3D printing could be implemented in. From electronics to optics, aerospace, automotive, mobility in general, small industrial manufacturing parts, and even consumer products. Also, and then we can go on to the next question, the biocompatibility of ceramics is great, because as we know, 3D printing can be used for excellent, personalized implants.

Lawrence: That all sounds wonderful. Ceramics is obviously a very important material, just considered as a material. But talk to us a little bit about the key obstacles to wide-spread adoption. I remember at RAPID, two years ago, people were getting excited about ceramics, and now it's here. But, there's always something that holds these things back a little. Perhaps you can talk a little more about what those things are.

Davide: The first obstacle is that ceramics has not been implemented for production. 3D printed ceramics has not been implemented massively, yet. One of the things I didn't mention is that a lot of companies simply don't know about the possibilities of what you could really do with 3D printing of ceramics. That's one aspect. The other issue is that it is a younger technology. You know, 3D printing dates back to '86. The first ceramics 3D printing started in the late 1990s, but still, that's about 15 years after polymer 3D printing. So, we need some time.

Then, there are process-specific issues. The fact that you need to be able to 3D print parts to full density. That's how you can benefit the most from ceramics. Of course, this is relative because, in a way, with 3D printing you can control the porosity and the density, which is actually achieved fully. This turns into another advantage. But right now, there can be limits in the density of the final parts, cracking of the final parts, the fact that the parts shrink.

So, you have to 3D print it with real high precision because you have to consider the high-shrinkage rate in the firing process. It makes the 3D printing process more complicated. Especially because technical ceramics in particular, are used to make very precise, small parts, so the tolerances are extremely important. The 3D printing process needs

to be able to meet these tolerance requirements, and there are real solution issues.

Of course, the more advanced 3D printing technologies have real high precision, but they're very young technologies. The extrusion technologies have an issue with precision, with layer dimensions. But all these are really being addressed very rapidly. One last thing is that the one 3D printing technology that we want to use for production is direct laser sintering. We use it for plastic, we use it for metals. But, you can't yet do it for ceramics because these are materials that are really complicated to work. Imagine the precision you need for a high-powered laser tool to melt that ceramic material. We have these issues with metals. Metals are a lot easier to work than ceramics are.

Lawrence: We included some very granular forecasts in the report and we actually did two scenarios. Ceramics is at an early stage right now, so we included a minimal scenario. We think that the more realistic scenario is that, because ceramics are a common material, that this will take off quite nicely. Perhaps you can talk a little bit more about where the revenues will be found and where the opportunities are.

Davide: Our forecast includes both technical ceramics, the really high-end ceramics for technical parts, and general, traditional ceramics, that are used for industrial molds and for consumer products. As we see it, this market is driven by actual adopters and our "realistic" scenario reflects this. If it were driven by the technology and materials manufacturers, ceramics printing would remain largely experimental and it would just take longer for the market to really take off. This would be our minimal scenario.

Now, in the more likely scenario, considering the overall market scenario, we're forecasting a $3-billion revenue opportunity by 2027. Companies that find ways to produce internally the parts that they need more efficiently, better parts, more functional. These are mostly companies that work in aerospace, that work in the medical sector, in transport in general, and in electronics. So, these are all really, really, really large sectors that use ceramics a lot. Ceramics offer significant advantages to these segments. So, these should be the biggest value opportunities. These value opportunities would be driving the demand for hardware and for materials.

2025 Library Avenue Suite 402
Crozet, VA 22932
http://www.smartechpublishing.com

Now, this is kind of a long topic. We went over the three minutes, but I think we should stay focused on this just a little bit longer. I want to give an idea of what numbers we have in mind. We are forecasting in the more likely scenario that these challenges will be overcome by around 2022.

Most process challenges for production will be overcome by around 2022. We'll have a little spike in growth after that, driven by adoption. This will, in turn, for example, begin to drive the hardware sales. In 2022, we're seeing that the hardware market will reach about a hundred million dollars, globally, in machine sales. Then in 2023, it will double. That's when the hardware market will start to take off. By hardware, we mean traditional ceramics hardware and technical ceramics hardware, combined.

The materials market is a little more complicated because—especially the technical ceramics market—these are parts that have a really high value but the parts are really small. So, it's a really high-profit opportunity. The part itself would have very low cost in terms of material because the parts are so small, but they generate a high value for the company.

For example, with the technical ceramics market, we're only seeing a $34-million market, even at the end of the forecast period. So, it's still a small segment, but very highly profitable for the companies that produce it. And the companies that buy, can get a lot of value out of it. With traditional ceramics, it's different. In this case, the quantities of materials are a lot bigger but the cost of the material is much lower.

Another segment is that of service. In both scenarios, we're seeing service remain at more or less the same levels because in an application driven scenario, it would be the companies doing most of the production internally, while in a hardware-driven scenario, the few companies that would adopt it would mostly get the parts done through services. So, a higher percentage of the market in the lower scenario and a lower percentage of the market in the higher scenario, but either way, we're seeing traditional and technical ceramics services build into a $100-million opportunity by the end of the forecast period.

The biggest opportunity, the $1 billion opportunity, is the parts. The parts themselves. It's $1 billion by 2027 for traditional parts, and $1 billion for technical parts.

Lawrence: Let's go back to some of the technical issues. What kind of 3D printing technology is being used right now? You make a point that there isn't actually very much ceramics being printed right now, but what's the thinking on what to do, right now, if you have to print ceramics?

Davide: This ties back to our double scenario because, right now, in a way, you can run a parallel scenario to the traditional 3D printing industry in that the first technology is stereolithography. The first polymer technology is stereolithography and the first ceramics technology is stereolithography. By the way, it's exactly the same stereolithography that is used for polymers. Meaning that there is SLA, laser stereolithography, or DLP, digital light projection stereolithography. The results are very similar. The issues that surround the technology are the same as they are for polymers. This is one segment. Stereolithography right now is mostly for technical ceramics. But we're already seeing some low-cost ceramics stereolithography starting up. This would bring about a much higher adoption.

The other thing is that the other technology that has been used is binder jetting. It offers the advantages of the powder bed technology, because that's the only powder bed technology that you can use ceramics on right now. There's so much to say about this. On one side, binder jetting is considered a slower technology because it's a two-step process with extensive post-processing required, which is the firing. Of course, this is how you do ceramics.

The other thing is that even with metals, we're seeing a going back to binder jetting, because it is a very fast technology. It's a very adaptable technology. You can do a lot of different things with it. You can control the porosity of the material a lot. So we're seeing a lot of adoption of binder jetting, both for traditional ceramics—so, the silica sands that are used for industrial molds—but also for some technical ceramics, because you can get down to a pretty high resolution with binder jetting as well.

Then, there are all the other technologies. There is extrusion. Except for glass, you cannot do any thermal extrusion with ceramics. But, you can do pneumatic extrusion, with post-processing. There is research being done on other technologies, but especially there is a lot of research being done on laser sintering, because the possibility to produce a part directly without the firing in the post-processing phase would be a real breakthrough for ceramics manufacturing. There are some very sporadic examples. Like Phenix, the company that was taken over by 3D Systems for SLM technology. They developed a technology for working with ceramics. And there's this small company in France that also developed a process that can 3D print using SLM technology and a titanium ceramics alloy material. But this is very early stage. It's going to come, but we're thinking it's going to take at least about five years.

Of course, there is HP. HP's technology is really bringing about a big change in the industry overall, as far as using 3D printing for production. HP Multi Jet fusion technology has already experimented with ceramics. Mostly as a binder process. But, it could possibly do direct production as well.

Lawrence: We talked about the numbers and we've talked about the pros and cons of 3D printing ceramics. Talk a little bit about where you see the applications, both now or a few years from now, and then more distant applications. What industry segments are expected to be tied in and with what specific applications?

Davide: There are a lot of ceramics out there. Obviously, you could use any ceramics in 3D printing, but you need to do R&D. So, there are some materials that have already been researched. These are, first and foremost, zirconia and alumina ceramics. Zirconia is the more high-end of the widely available 3D printable ceramics. Alumina is a great material and it's also less expensive than zirconia.

Zirconia offers the advantage that it is extremely hard, resistant to abrasion, resistant to temperature, and very low friction coefficient. By the way, zirconia is a material based on zirconium and oxide. So, it's zirconium dioxide. It has characteristics of biocompatibility. It's extremely heat-resistant. It's even radiation-resistant. So, it's got so many excellent qualities. Alumina also has high mechanical strength, high resistance to chemical agents and high temperatures. There's a lot of advantages to these materials.

Now, the least expensive materials are generally the silicon-based ones. Of course, ceramics theoretically also includes cement and glass, but in this report, we only considered silica sands which are used for industrial molds and foundry cores. Finally, but this is very, very early stage, there are non-oxide ceramics that are used in technical 3D printing. So, silicon carbide and silicon nitride. These are very high-end materials with really high properties. But right now, it's one of the more expensive materials that can be used.

Okay, moving on to applications. The main ones are aerospace, and in aerospace, there are several flight-control components that could be produced; hydraulic shields, thermal protection components. Imagine just for atmosphere re-entry, for space applications, a lot of these parts are ceramic parts. Of course, they're big ceramic parts, so the size of the machine has to improve. But it is growing.

Then the same applications for defense. A lot of armor components. Imagine custom armors, both for humans and for vehicles. In automotive, as well, there is a lot of components; powertrain components, interior sensors, other interior applications. But, most of all, and beyond these segments, is electronics. In electronics and optics, there are so many small parts that need to be very precise, very complex, that could benefit from adopting technical ceramics 3D printing processes.

Also, marine. The resistance to chemical agents makes ceramics ideal for marine applications, and there are a lot of 3D printable marine applications. Then, some of the biggest are medical and dental. Dental is already all ceramics so, it's a natural shift to directly 3D printed ceramic parts and it's a huge potential market. Same for medical implants.

Lawrence: Can you talk about some key businesses, some key companies that are active in this space and really ones to watch for the future of 3D-printed ceramics? Big and large companies.

Davide: We were saying this before. After we published this report, two larger companies announced new activities directly in 3D printing of ceramics. One is Johnson Matthey, that announced its ceramics 3D printing division, based on the binder jetting process, but, of technical ceramics. And the other one is this company called HSL, which signed an agreement with NASA to produce aerospace parts. There are other very interesting companies producing aerospace parts. One is called OSE—Optimized System Engineering.

Now, let me go to the hardware manufacturers. I know that I said that the market cannot be driven just by the hardware manufacturers/technology providers, but they are the ones that are developing the technology. The main ones to look at are 3DCERAM, it's a French company. It started as a service, so it is mostly focused on serving and producing the part. But now its machine is also available to buy. It's a very high-end machine for technical ceramics using stereolithography. The other one is LITHOZ, another major player. It's an Austrian company, and it is more focused on selling machines. These are the two main ones.

There are other ones. There's Prodways in France and there is Admatec in the Netherlands, also working on ceramic technology. In the U.S.,

there are a few interesting companies, especially in stereolithography. There is a company called DDM Systems.

Another very interesting company in the U.S. is called Boston Ceramics. It was founded by the person that developed one of the first binder jetting 3D printing companies and then sold it to 3D Systems. Then he came out and funded his own company. They used the binder jetting process. There's another company using binder jetting in Germany called WVR. And of course, then there is the future. HP is working on this. There's another very interesting company called XJET, that's working on 3D printing of nanoparticle ceramics. It's a very interesting process because it could do multi-materials in a single print, which is a whole other subject. And then there are the big binder jetting companies. So, Voxeljet and ExOne. They are the ones that make really, really large-sized industrial molds and foundry cores.

Lawrence: This completes today's session. It was fascinating.

The direct link to this ceramics report is: Ceramics Additive Manufacturing for Production Parts: An Opportunity Analysis and Ten-Year Forecast.

If you have any further questions or are interested purchasing the report, please contact Robert Nolan at rob@smartechpublishing.com.

Thank you for attending today's session and we invite you to sign up for other events in the future.