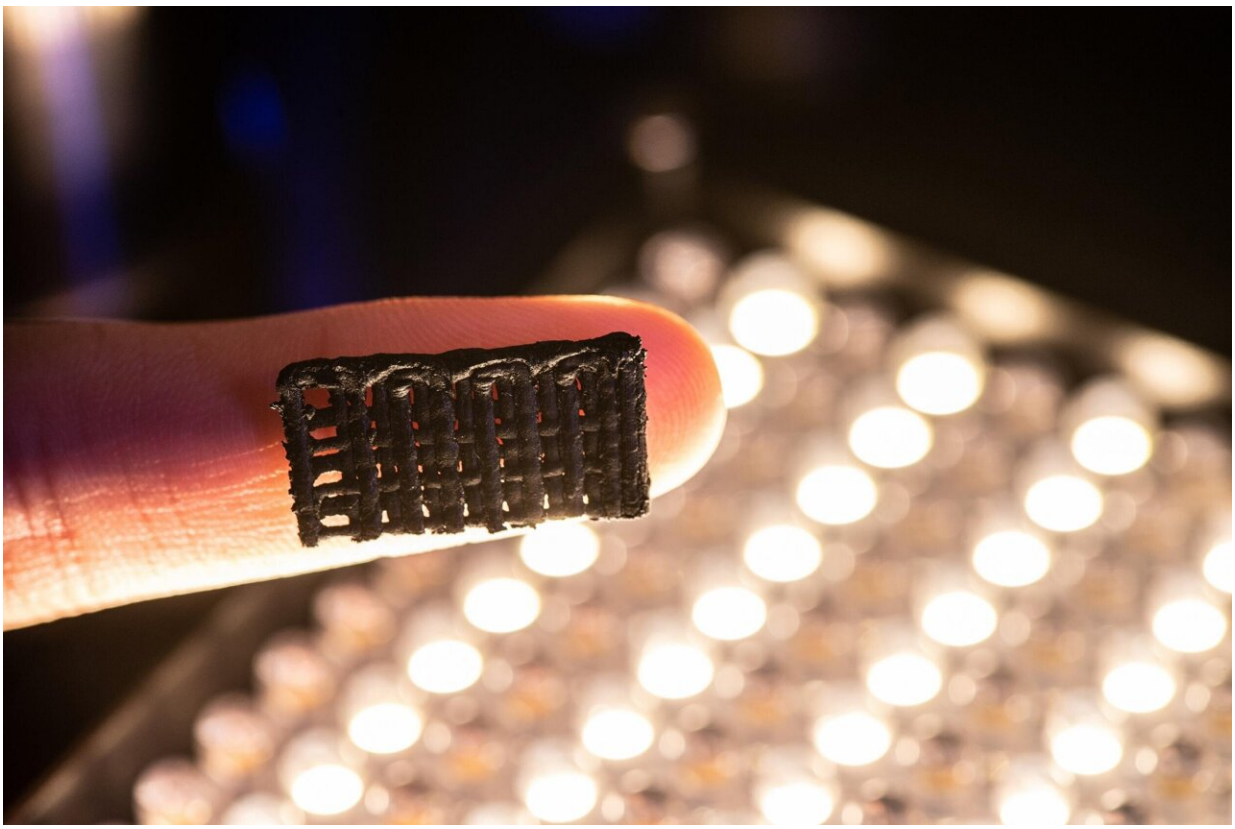
Student discovers 3D printable ink that 'everyone was looking for,' says physics professor

April 21 2023, by Mary Kate Brogan



Shar shows a close-up of the ink he hopes will be used in wearable monitoring devices. Credit: Allen Jones, Enterprise Marketing and Communications

Finding a 3D printable ink that conducts electricity, yet is strong,

flexible and stretchable, has been a goal of materials scientists around the world since 3D printing began, says Daeha Joung, Ph.D., an assistant professor in the Department of Physics at Virginia Commonwealth University's College of Humanities and Sciences.

So last year, when Andy Shar came into his lab eager to look for the solution, Joung was apprehensive but gave Shar a chance. And he is grateful he did.

"I was trying to find that ink myself," Joung said. "But somehow, Andy discovered the recipe."

The discovery has opened up new opportunities for Shar, now a sophomore majoring in biology in the College of Humanities and Sciences and minoring in religious studies in the School of World Studies. He has been working with Joung and his research team through the VCU Undergraduate Research Opportunities Program.

Alongside Phillip Glass, a student in the Ph.D. in nanoscience and nanotechnology program, Shar has published two academic papers, including one in the journal *Advanced Functional Materials* for which he served as the first author. He also has submitted another—plus a book chapter—and has been invited to present at conferences about the discovery.

"The material we discovered was a composite of silicone—polydimethylsiloxine, or PDMS—and we dispersed carbon nanotubes, or CNT, inside of that silicone, which is something that is kind of difficult to do," Shar said. "We used a pretty simple environmentally friendly technique to do it that can occur at room temperature. The fabrication process being easy allows it to be accessible to other people and maybe even companies who want to use it commercially."

Joung, Shar and Glass continue to use the 3D printable ink in the development of customizable patient health monitoring devices and of electronic skin, or eSkin—wearable sensors to detect motion of joints or monitor cardiac and respiratory health.

"What Dr. Joung has been really pioneering is using 3D printing to create scaffolds that can simulate the spinal cord architecture," Shar said. He and Joung hope this technology, infused with bioprinted information that would allow cells to regrow, can help people with spinal cord injuries regain sensory and motor function.

Here, student and mentor share thoughts on what they learned working together.

Andy Shar

What attracted you to this project?

I'll start from the beginning and go to what attracted me to Dr. Joung's lab in the first place: [my] past experience with high school research. I've always really liked hands-on stuff, and materials science and nanotechnology were two of my main interests coming into VCU. So I liked how he incorporated that with 3D printing—which was something I've never done before but was also excited to use—with biological applications. I intend to go into the medical field, so that would be something that would relate to my future profession. So that was definitely something of interest.

For that specific project, I actually started by working with Phillip Glass, who's a physics graduate student, on his project, and it just became a natural progression because I was helping him. I had some interest in chemistry and the process of making the ink and making the material. And as I was helping him, I decided to do my own trials. And I really

credit Dr. Joung for giving me the flexibility and independence to do that. I was experimenting around, and once I found an ink that I thought would work, then we decided that if it was unique enough and if it had certain advantages over what was seen in the literature, then we could write a paper about it. So I did more research there.

What did you get out of the experience?

There were a few things I got out of it. Definitely knowledge, learning about the materials science aspect of it, a lot of lessons in perseverance. It took dozens of trials—Dr. Joung has seen my array of vials with hundreds of failed attempts. So just being able to learn from your past mistakes. And I didn't give up, because I knew I was getting closer and closer to the end result.

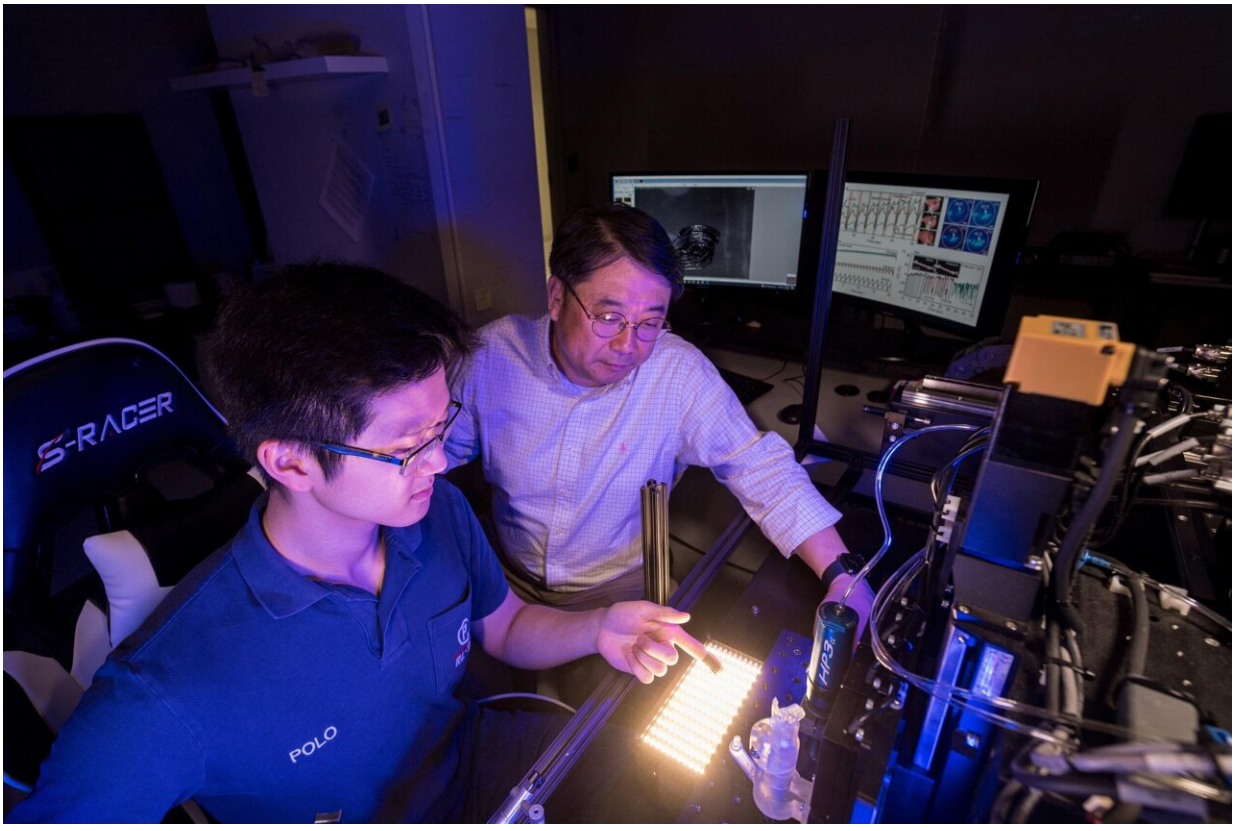
That was really a lesson that I learned, and I also think teamwork. As a group, we held meetings where we presented our findings, so you learn communication skills, how to interact with the group, how to just work with different (technologies)—how to use the gantry, how to use the texture analyzer, different machines—and then spreading that knowledge as well, and teaching other people who join the lab how to use those same machines.

And then, because of the project, I've also been able to present at multiple conferences—for example, the UROP Symposium, which I will be presenting at this spring, and the annual Network for Undergraduate Research in Virginia conference at Christopher Newport University, which was in January. Being able to present to the public and explain to them our findings in terms that they can understand is definitely a skill that I've learned.

What's one lesson you learned from Dr. Joung?

From Dr. Joung, I've learned really just how to be an effective PI [principal investigator]. It's about the coordination of an effective team and really encouraging teamwork and making sure everybody's staying involved, everybody is going at a pace that's comfortable for them but also making sure to push them a little bit. I remember Dr. Joung helping me out whenever I had certain trials not go the way I wanted to and then also setting certain deadlines for me, making sure I met them and just encouraging me to do my best.

I remember, especially during the summer, I was there for maybe 15 to 20 hours a week. And we were really trying to get the paper published. At the very end, it was a lot of data collection, a lot of writing. And I credit Dr. Joung with coordinating me and Phillip, and just making sure that we got everything done in time and that time management wasn't a problem. That's definitely a lesson I learned from him.



Andy Shar, left, and Daeha Joung, Ph.D., center, inspect the flexible 3D printing ink Andy has developed that conducts electricity, which will allow researchers in their lab and other scientists to make wearable devices and eSkin technologies that empower patients to better monitor and take charge of their health. Credit: Allen Jones, Enterprise Marketing and Communications

Daeha Joung

Why does this research matter?

eSkin technology is the future of wearable devices. So what Andy, Phillip and I found is that 3D printable electronic skins can be useful for patients who suffer from skin diseases. Or we can have one that does health monitoring so that it's a system where we can directly 3D-print into human organs. We can actually offer new therapeutic options. [As a physicist] I'm not going to use these directly with patients. However, this technology can be transferred to the operating room in the future. Then the patients can have the advantage to use this technology. That is our long-term goal for this project.

Let's say we developed a 3D printable electronic device, or wearable flexible device. Now we want to make a connection from this technology into the spinal cord regeneration project. With spinal cord regeneration, there are always issues because of the structural complexity, right? So one of the therapeutic options is stem cell and electrical stimulation therapy. What Andy is doing is adding to it. As Andy mentioned, I am a pioneer of printing stem cells for spinal cord injury regeneration. So now Andy is combining these stem cell printing technologies and these flexible electronics.

We want to test how these two different elements of technology can combine to create a new opportunity for spinal cord regeneration. Everything is kind of related. As physicists, as material scientists, as engineers, our long-term goal is we want to produce and provide new therapeutic options and potential future applications for treatments.

How did Andy help advance the project?

Even before Andy joined, I've been working on 3D-printing flexible electronics. But the point is that every researcher in the world has the problem of printing flexible and conductive ink. I think Andy spent around four or five months [on it].

He did the hard work on developing that ink that everyone, most every 3D-printing researcher, was looking for. Then Phillip, our graduate student, expanded the ink's capabilities and applied it to 3D-printed wearable devices. That's why their paper is in one of the top-tier materials science journals. When we talk about this paper, whenever I mention that the first author of this paper is a sophomore, people are amazed. Based on this, we got a lot of conference invitations. This is amazing work.

What's one lesson you learned from Andy?

Although Andy is an undergraduate, there are many things I learned from him, but the main thing was that I had doubted myself: "Can I give an independent project to an undergraduate student?" In general, many PIs do not really give independent projects to undergraduates, but Andy wanted to be very independent. He actually emphasized to me, "I can do it. I can do it." I was a little bit doubtful the very first time; however, I saw his motivation, so that's why I gave him independent projects. He did a great job, and I'm continuously giving him very independent

projects.

The way I've trained Andy is like a graduate student. So for me, with Andy and the other graduate students, our training for Andy is all the same.

Beyond the knowledge he's developed and the ink discovery, Andy is a very motivated student-researcher, so he has a strong sense of responsibility. Research is not only about being smart. Research is about where you get the motivation and what excites you. Andy's an undergraduate student and sophomore who wants to apply to medical school, especially M.D.-Ph.D. programs. I give a lot of credit to Andy—consider how busy he is; however, he still spends a lot of time in the lab. I could see that. I could see he's so excited, and he enjoys his time in the research lab. He's always smiling, and he always has energy to do new challenges.

So to come back to the question of what I learned from Andy: Motivation is the most important factor to be successful in research.

More information: Andy Shar et al, 3D Printable One-Part Carbon Nanotube-Elastomer Ink for Health Monitoring Applications, *Advanced Functional Materials* (2022). DOI: 10.1002/adfm.202211079

Provided by Virginia Commonwealth University