FACES OF MASS SPECTROMETRY / Mazdak Taghioskoui

Anne Brenner and J.D. Brookbank are science writers at Technica Editorial Services.

July 2024

Seeing Beyond Today's Limits

Dr. Mazdak Taghioskoui is an inventor, engineer, and entrepreneur. He grew up in Tabriz, Iran, where his father worked as a Professor of Pharmacy, and this is what ignited Mazdak's curiosity and passion for the sciences. After earning a degree in electrical engineering from Sharif University of Technology in Tehran, Mazdak moved to the United States to continue his education. He attended George Washington University where he received a master's degree in chemistry followed by a PhD in electrical and computer engineering. It was during this time that Mazdak became seriously interested in the field of mass spectrometry, particularly its applications for space exploration.

These days, Mazdak is immersed in the management and operation of Trace Matters, the technology startup he founded. The company focuses on the development and commercialization of innovative mass spectrometry instrumentation, much of which is tailored for space applications. A frequent collaborator with NASA, Mazdak was the recipient of the 2020 Entrepreneurship Award from NASA's Science Mission Directorate. This award recognized his invention of the Sequentially-Packaged Ion Transfer device, named SPion, which was designed to move ions from a rover's arm to its main body. Another current collaboration involves the development of a customized plasma mass spectrometer designed for use during lunar missions.

With a background in engineering, and as the founder of his own startup, Mazdak brings a unique perspective and innovative mindset to the world of mass spec. He believes that creativity, resilience, and patience are valuable keys to success for researchers and entrepreneurs alike. And when it comes to problem-solving, Mazdak underscores the importance of looking at issues from multiple angles and considering a variety of different perspectives.

How did you first get interested in engineering, and how did this eventually lead to your interest in mass spec?

My path into mass spectrometry, and science in general, was deeply shaped when I was growing up in Iran by my father, a dedicated scientist whose passion for discovery and innovation always inspired me. I vividly remember my first encounter with a mass spectrometer in his lab, where he was analyzing a new molecule with therapeutic effects for a potential new pharmaceutical that helped with migraines. Following his example, I set up a mini version of his wet lab in our basement, turning it into my own exploration space. I have acid marks on my hand from pure sulfuric acid, and I stupidly licked mercury to see how it tastes! And that was because my resources were limited—there was no internet back then, and my only reference at the time was a chemistry encyclopedia my father borrowed for me from their library, and it did not have the information. On top of that, the encyclopedia was difficult for me to understand, because it was in English, and English is only my third language—my first and second languages are Turkish and Farsi. But at the time, I was able to identify many organic solvents just by their smell.

My passion for chemistry was further fueled in high school by my chemistry teacher, Mr. Behkam, which made chemistry even more fun and exciting. I grew up in Tabriz, Iran, and despite my deep desire to become a chemistry major in college, I pursued electrical engineering at Sharif University of Technology. It is located in Tehran, Iran's capital city, and it is often described as Iran's MIT. This choice laid the groundwork for my future, as electrical engineering became the base for my understanding and innovation in mass spectrometry instrumentation, even though at the time I was not sure where or how I would be deploying all my energy and passion for science. After obtaining my undergraduate degree, I moved to the United States to pursue my master's degree in chemistry at George Washington University, followed by my PhD in Electrical and Computer Engineering. That's where I really got hands-on with mass spectrometry. I was fascinated by how complex a mass spec was and all the opportunities there were to come up with and try new ideas. It reminded me of

When I was an undergraduate student, one professor said it best: "When you're trying to solve a problem, first put yourself in the shoes of an ant, and then put yourself in the shoes of an elephant."

(Photo courtesy of Mazdak Taghioskoui.)

the experiments I did in the basement lab with the advantage that the experiments were more complex and there were great opportunities for trying and finding new things

When did you first begin to have an interest in mass spec as it relates to space applications?

During my PhD program, I got really interested in how mass spectrometry is used in space exploration. I worked on creating new ion sources for mass spectrometry, like a small plasma source that seemed perfect for space missions. I was not sure how to engage with NASA. So, I started submitting proposals to them, and after several rejections, they finally took a chance and provided some initial funding for the project. This allowed me to show how well this technology could work for space missions, and the project has grown bigger and bigger from there. Now, this project has been going on for seven years, and I am a member of a great team working together to build a one-of-a-kind flight-qualified plasma mass spectrometer for lunar missions.

Getting support from NASA was a game-changer for me. It turned my PhD research into an exciting new technology for space exploration. Working on a small mass spectrometer for moon missions has been one of the most satisfying parts of my career. Working with and learning from the team at NASA, who are all incredibly talented and humble scientists, has been an extraordinary experience. Their dedication, intelligence, and resilience in the face of challenges have taught me a lot about perseverance, patience, teamwork, and maintaining hope during difficult times. To anyone from NASA who might be reading this, I want to say a big thank you. Working together on these projects has been amazing, and I'm so grateful for the opportunity.

Tell us about your current company, Trace Matters.

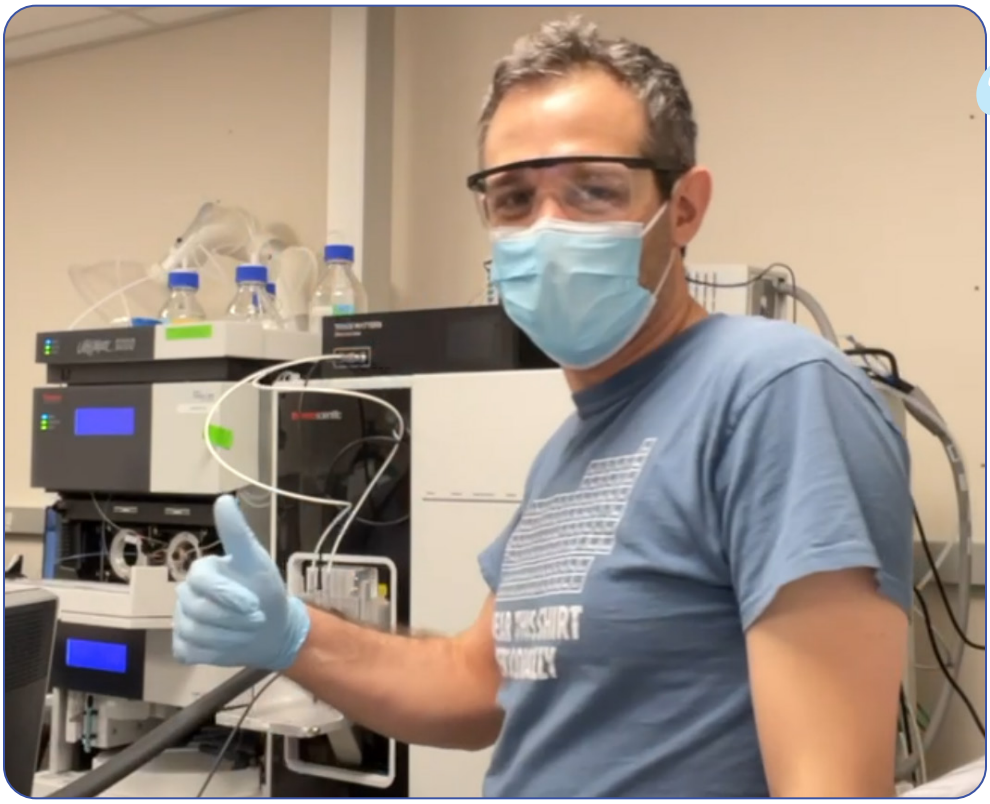
Trace Matters started from my curiosity about mass spectrometers, especially wanting to understand what happens inside them with the ions (Figure 1). During my PhD program, I never got to explore inside these instruments, so I founded Trace Matters to build one from scratch. I noticed NASA had very strong mass spectrometers that weren't available in the market, so I began working with NASA to develop new technologies for them and to make NASA's advancements available to everyone.

One key innovation came from a project with NASA, where we needed to move ions from a rover's arm to its main body, but no technology existed for this. So, I invented something called SPion (Figures 2–4), which stands for Sequentially-Packed Ion Transfer Device. SPion is special because it can move ions between two analytical systems, and in a flexible path. Also, a novel ion transfer mechanism resulted from these efforts that enables grouping ions together and transporting them in a new way we call SPion Motion. SPion has opened up many new possibilities. For instance, it led to the development of a new scalable architecture for mass spectrometry, "super mass spectrometry," where we use multiple mass spectrometers together to scale analytical performance, particularly for protein research. All these technologies are category-defining inventions and solve some of the fundamental limitations in the field.

The development of SPion also led to my winning the 2020 Entrepreneurship Award from NASA, which was a really big moment for me. It showed the value of working together across different areas of science to tackle tough problems and create new tools that change what we can do with scientific instruments. I have learned that it's all about looking at problems from different perspectives. That's the approach that will allow you to best understand the problem, in mass spec and beyond. When I was an undergraduate student, one professor said it best: "When you're trying to solve a problem, first put yourself in the shoes of an ant, and then put yourself in the shoes of an elephant."

What advice would you give to others who are perhaps interested in mass spec, but who, like you, first pursued a different career path?

If you're interested in mass spectrometry but have a different job background, my biggest tip is to not listen to people who say you can't do it. Getting into mass spectrometry can be tough



> *If you're interested in mass spectrometry but have a different job background, my biggest tip is to not listen to people who say you can't do it.*

Mazdak working in the lab connecting SPion to a mass spectrometer. (Photo courtesy of Mazdak Taghioskoui.)

because it often looks for big new ideas from people who have been around for a while. But don't let that stop you. Push forward. Mass spectrometry brings together a lot of different areas like engineering, computer science, chemistry, biology, and more. Having skills in these different areas is actually good. It means you can bring new ideas to mass spectrometry. I suggest learning more about these areas because it helps a lot—conferences can be great for this purpose, too. It makes it possible to do new things in mass spectrometry that haven't been done before. Even though mass spectrometry is important, it's not a huge market—it encompasses only about $4 billion, which is a relatively small market. But this means there's a lot of room for new ideas and growth. Mass spectrometry isn't valued as much as it could be, which means there are lots of chances to do something more impactful. So, if you're coming from a different job area, this is a great chance to make a difference. Your different skills and ways of looking at things are just what we need.

Can you share something about your success as an entrepreneur, such as a key lesson learned or an obstacle you had to overcome?

Running Trace Matters has been a journey full of new challenges and learning opportunities every single day. I find myself handling a wide array of tasks, ranging from developing technology to diving into marketing, strategizing the business direction, and even navigating legal matters. A key lesson I've learned through this process is the direct correlation between the quality of my work and the outcomes we achieve. This realization motivates me to consistently strive for excellence. Creativity plays a crucial role in this endeavor. It's not limited to the technological aspects of our work but extends across the entire business spectrum. Finding innovative and practical solutions to the diverse challenges that come our way is essential.

One of the major obstacles in running a startup, especially in a field as complex as mass spectrometry, is the resilience and patience required in the face of frequent rejections. Hearing "no" becomes a part of the process, but it only takes one transformative "yes" to significantly propel us forward. In essence, entrepreneurship is not solely about pioneering innovative technologies; it's equally about applying an innovative approach to decision-making and overcoming obstacles. In the startup environment, barriers that might halt progress in a larger company can often be transformed into opportunities for differentiation. This mindset of innovation is crucial for success, especially when tackling the sophisticated challenges involved in developing new technologies for mass spectrometry.

What are some qualities you consider important for innovators in your field?

In the world of mass spectrometry, knowing a lot about different subjects is very important. This field touches on many areas like physics, chemistry, biology, and engineering. When you understand a bit of everything, you can come up with new ideas that mix these areas in exciting ways. It's also key to keep trying, even when things seem tough, or people say it can't be done. Sometimes, the best inventions are found in the hardest problems. Being creative and thinking differently can lead to big breakthroughs. Patience and not giving up are crucial. You might face a lot of "no answers" or find that your ideas don't work at first. But staying strong and pushing ahead can lead you to success.

To anyone from NASA who might be reading this, I want to say a big thank you. Working together on these projects has been amazing, and I'm so grateful for the opportunity.

Mazdak introducing SPion for the first time at the 69th ASMS Conference on Mass Spectrometry and Allied Topics (ASMS 2021), which took place from October 31 through November 4, 2021 in Philadelphia, PA, USA. (Photo courtesy of Mazdak Taghioskoui.)

Being able to change and adapt is another important skill. This field changes fast, so being open to new information and ready to shift your approach can help you stay ahead. Lastly, having a big dream or vision is essential. It's not just about making small changes but imagining what could be possible and going for it. This drive to see beyond today's limits can inspire new directions and achievements in mass spectrometry.

What are some of your interests outside of the lab?

Those types of moments are rare for me, because there's so much work associated with having a startup. You're wearing many different hats. One day you're dealing with legal issues, the next day it's filing patents, the next day it's inventing, and so on. I also have two kids, and even after they have gone to sleep, I'm typically still working at all hours of the night. So, it's tough but extremely fulfilling. I have a print-out on my desk that says, "hard things are hard."

When I was younger, I had several hobbies that I don't have as much time for now, such as painting watercolor professionally. But one hobby that I have been able to keep up with is playing soccer—that just helps me release energy and kind of disconnect from the world. Some of my old classmates have rented an indoor playing area, and we play for an hour or so every Thursday on that turf. We've kept that going for almost 15 years now!

Are there any big projects or new questions on the horizon for you and your team?

At Trace Matters, we're all about trying new things and doing things that people thought for decades couldn't be done. Our goal is to go further in mass spectrometry than anyone has gone before. Super mass spectrometry is a particularly exciting technology that addresses the grand challenges of proteomics measurements. This innovative approach overcomes the fundamental limitations of traditional systems. Trace Matters' category-defining technologies have caught the attention and interest of numerous parties, and we have several exciting projects underway. We're thrilled about the future of mass spectrometry and the role Trace Matters' technologies will play in shaping it. With our innovative technologies and collaborative approach, we're poised to make significant strides in this field and contribute to groundbreaking discoveries across various disciplines!