Agilent Case Study: A conversation with Dr. Jared Bruce, physical chemist at UNLV

Clarifying the Connection Between Cause and Effect

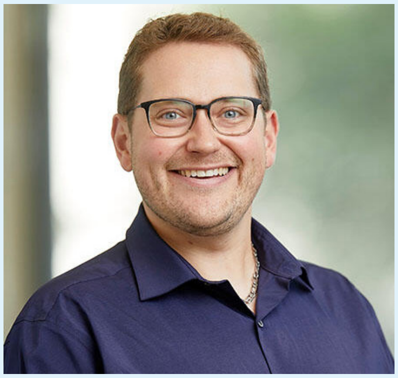
In the physical world, an interface is a special region that represents both boundary and connection – a place where independent and often unrelated systems meet and interact. Interesting things can happen at interfaces that don't occur anywhere else.

Case in point: photochemistry, which typically involves the physicochemical effects caused by the absorption of incident light by an active surface. Photochemistry proceeds through pathways not easily accessible, opening opportunities for new chemical processes that require new research approaches to understand and exploit.

Dr. Jared Bruce, assistant professor of physical chemistry at the University of Nevada Las Vegas (UNLV), is ideally suited for pursuing such avenues of investigation. Leader of the Interfacial Photochemistry group at UNLV, Dr. Bruce's background spans multiple disciplines that have combined to enable his highly individual approach.

"My training included a lot of chemistry, physics, and surface science," he said. "Bringing these different areas together makes for an interesting mix that characterizes and drives my group's work. Specifically, one part of our work looks at electrocatalysts, which are good at promoting electrochemical reactions, and photo absorbers, which are specialized for absorbing light. Coupling these systems together opens opportunities for creating new ways to use light to drive electrochemistry; understanding how these systems interface and interact with each other is, I think, the really exciting part of what we do."

A familiar example of this is the science that underpins the field of solar energy, where photons passing through our atmosphere strike special materials, called photovoltaic cells, that convert the energy of those photons into electricity. However, as Dr. Bruce points out, this scenario, which occurs at the interface of our gaseous atmosphere and a solid panel surface, represents only one of many possibilities.



Dr. Jared P. Bruce
Department of Chemistry and Biochemistry
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Dr. Jared P. Bruce, originally from Balmoral, Manitoba, Canada, completed his undergraduate degree in Chemistry at the University of Manitoba. He continued with a Masters under Professor Michael Freund, spending time at the California Institute of Technology with Professors Harry Gray and Nathan Lewis, where he learned to modify semiconductor surfaces.

Jared then pursued his Doctoral work at the University of California, Irvine with Professor John C. Hemminger, focusing on near ambient pressure photoelectron spectroscopy to investigate small molecule solvation at liquid surfaces. His research took him to various synchrotron facilities across the US and Europe.

After his PhD, Jared moved to Berlin for postdoctoral work at the Fritz Haber Institute with Professor Beatriz Roldan Cuenya, focusing on low temperature scanning tunneling microscopy and electrochemistry to study carbon dioxide reduction on single crystal copper surfaces.

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"A lot of current research, such as the development of new battery technologies and more efficient electric vehicles, are driving interest in a general trend toward the electrification of industrial processes," he explained. "Typically, industrial reactions occur at gas–solid interfaces, but the possibility of carrying out some of these processes in the liquid phase is really exciting, and a lot of companies all over the world are actively pursuing it. I think the very first step is to understand, at a really fundamental level, how electro- and photoactive materials behave. During my postdoctoral work at the Fritz Haber Institute in Berlin, it seemed that many of the questions being asked by others in the field weren't focused on the surface itself. It turns out to be really difficult to isolate surfaces and look at them in a way that makes you certain that what you're observing correlates directly to changes in the surface. Isolating a material system in this way is a slow, arduous process, but you learn things that are deep and fundamental to the system. When we started doing that, we began to see processes happening that were in some ways different than what had been reported in the literature."

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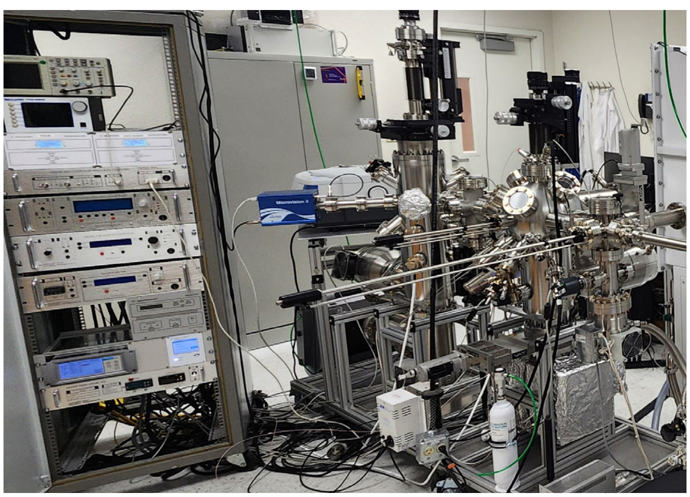

Image 1. Ultrahigh vacuum conditions allow for a controlled examination of the interactions between photocatalysts and electrocatalysts

Isolation of this magnitude requires, among other things, creating conditions of very high vacuum. Unfortunately, vacuum – as Aristotle and Spinoza remind us – is something nature abhors. To help him get there, Dr. Bruce enlisted Agilent and the wide variety of pumps, leak detection systems, and expertise they offered.

""Partnering with Agilent has taken a lot of stress off my shoulders; their responsiveness and collaborative approach have helped me realize the vision of moving my work forward."

"Vacuum is crucial to our work in a number of ways," he explained. "In some applications, we need to create an environment that minimizes any effects caused by gas molecules in the atmosphere, which can lead to side reactions that we want to avoid. In these cases, vacuum is essential, and the higher the better. By establishing and maintaining ultrahigh vacuum conditions, we can really look at the interaction between photocatalysts and electrocatalysts in a controlled manner. We're able to design model systems and then test how they behave in the real world. Partnering with Agilent has taken a lot of stress off my shoulders; their responsiveness and collaborative approach have helped me realize the vision of moving my work forward. Being able to rely on the vacuum system gives us confidence that any interesting behavior we see is actually due to the materials of interest. Then we can introduce these materials into ambient conditions and see how that alters their behavior."

In some ways, aspects of Dr. Bruce's work can be viewed as filling important gaps between more conventional, established approaches. This reality is mirrored in the way his lab works and the skills his students need to develop to succeed.

"My lab is dominated by one piece of equipment, and the work is very hands-on," he said. "My students are directly involved in the day-to-day challenges of setting up experiments and maintaining the vacuum system; there aren't any "pushbutton" outcomes. The instrument itself has two separate chambers, one of which allows us to do metal deposition, introduce variables like gases or heat, and carry out certain types of spectroscopy that inform us about the synthesis. Connected to that is a second chamber with different capabilities that allow us to closely examine the properties of the newly created surface. With this approach, we're able to connect the synthesis and the characterization of new systems in a way that's completely isolated, so that they never touch the ambient conditions of the outside world.

"This is a level of control that not many groups have, so in some ways it's like having a clearer window into the connection between events at the surface and the reaction outcomes," he continued. "Even more exciting, we are working toward being able to make these observations in situ and operando – that is, where and while they are occurring. That sort of direct connection between cause and effect is the real power of what we hope to achieve."

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