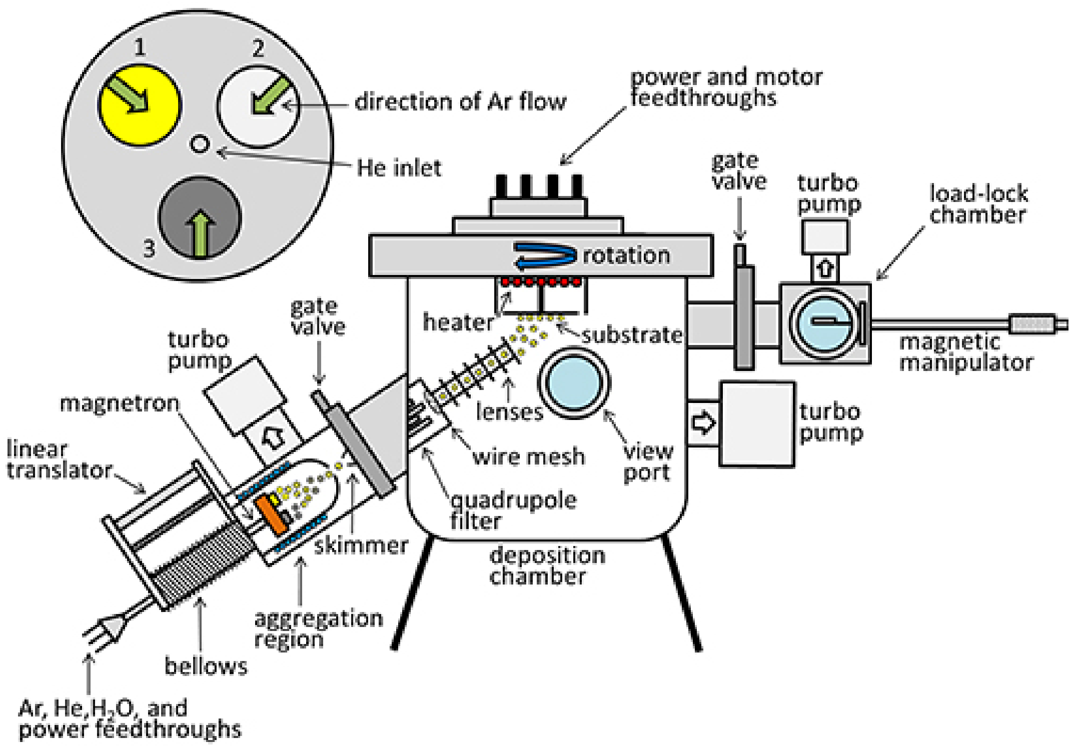
Insights into potential substitutes for costly platinum in fuel cell catalysts

April 13 2015



Scientists at Pacific Northwest National Laboratory created metal alloy particles using a technique that involves magnetron sputtering and gas aggregation. They placed them on a surface using ion soft landing techniques. Credit: Johnson et al. with permission from the Royal Society of Chemistry.

Platinum's scarcity hinders widespread use of fuel cells, which provide power efficiently and without pollutants. Replacing some or all of this rare and expensive metal with common metals in a reactive, highly tunable nanoparticle form may expand fuel cell use. At Pacific Northwest National Laboratory, scientists made such metal nanoparticles with a new gas-based technique and ion soft landing. As an added benefit, the particles are bare, without a capping layer that coats their surfaces and reduces their reactivity.

Replacing inefficient and polluting combustion engines with fuel cells is not currently feasible because the cells require platinum-based catalysts. The PNNL study shows how to create particles with a similar reactivity to platinum that replace some of the platinum with Earth-abundant metals. The implications of this new preparation technique go far beyond fuel cells. It may be used to create alloy nanomaterials for solar cells, heterogeneous catalysts for a variety of chemical reactions, and energy storage devices.

"The new method gives scientists fine control over the composition and morphology of the alloy nanoparticles on surfaces," said Dr. Grant Johnson, a PNNL physical chemist who led the study.

The team created the nanoparticles using magnetron sputtering and gas aggregation. They placed them on a surface using ion soft landing techniques devised at PNNL. The result is a layer of bare nanoparticles made from two different metals that is free of capping layers, residual reactants, and solvent molecules that are unavoidable with particles synthesized in solution.

The process begins when the scientists load 1-inch-diameter metal discs into an instrument that combines particle formation and ion deposition. Once the metals are locked into a vacuum chamber in the aggregation region, argon gas is introduced. In the presence of a large voltage the argon becomes ionized and vaporizes the metals through sputtering. The metal ions travel through a cooled region where they collide with each other and stick together. The result is bare ionic metal nanoparticles that are about 4 to 10 nanometers across. The mass spectrometer filters the ionic particles, removing those that don't meet the desired size. The filtered particles are then soft landed onto a surface of choice, such as glassy carbon, a commonly used electrode material.

Creating the alloy particles in the gas phase provides a host of benefits. The conventional solution-based approach often results in clumps of the different metals, rather than homogeneous nanoparticles with the desired shape. Further, the particles lack a capping layer. This eliminates the need to remove these layers and clean the particles, which makes them more efficient to use.

"An important benefit is that it allows us to skirt certain thermodynamic limitations that occur when the particles are created in solution," said Johnson. "This allows us to create alloys with consistent elemental constituents and conformation. Furthermore, the kinetically limited gas-phase approach also enables the deposition of intermediate species that would react away in solution."

The coverage of the resulting surface is controlled by how long the particles are aimed at the surface and the intensity of the ion beam. At relatively short time frames on flat surfaces, the nanoparticles bind randomly. Leave the process running longer and a continuous film forms. Stepped surfaces result in the nanoparticles forming linear chains on the step edges at low coverage. With longer times and a surface with defects, the particles cluster on the imperfections, providing a way to tailor surfaces with particle-rich areas and adjacent open spaces. The characterization experiments were done using the atomic force microscope, scanning and transmission electron microscopes, as well as other tools in DOE's EMSL, a national scientific user facility.

While this work focuses on single nanoparticles, the final result is an extended array with implications that stretch from the atomic scale to the mesoscale. "Mesoscale research is about how things work together in extended arrays," said Johnson, "and, that's exactly what we've successfully built here."

The researchers are now exploring different metal combinations with various platinum ratios to get the desired characteristics for fuel cell catalysts. They plan on further studying these particles in the new in situ transmission electron microscope, planned to open in EMSL in 2015, to understand how the particles evolve in reactive environments.

More information: "Soft Landing of Bare Nanoparticles with Controlled Size, Composition, and Morphology." *Nanoscale* 7:3491-3503. DOI: 10.1039/c4nr06758d

Provided by Pacific Northwest National Laboratory

Citation: Insights into potential substitutes for costly platinum in fuel cell catalysts (2015, April 13) retrieved 25 April 2024 from https://phys.org/news/2015-04-insights-potential-substitutes-costly-platinum.html