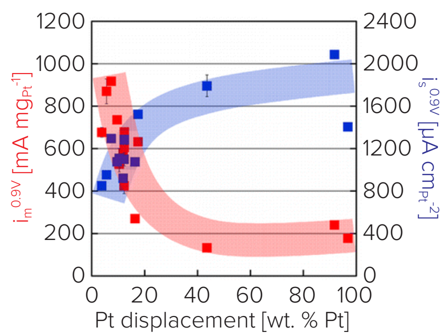
# PROTON EXCHANGE MEMBRANE FUEL CELLS:
# PT GROUP METAL ELECTROCATALYSTS

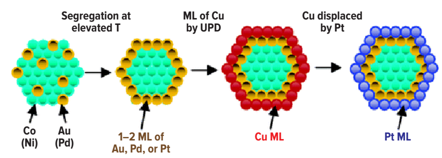
**Proton Exchange Membrane (PEM) fuel cells are increasingly used in applications such as automotive, material handling equipment or backup power, but many PEM fuel cells are still under development. This IP bundle combines the expertise in fuel cell electrocatalysts research from Brookhaven National Laboratory (BNL), Argonne National Laboratory (Argonne), and National Renewable Energy Laboratory (NREL). The emphasis is on novel Pt group metal electrocatalysts to significantly improve fuel cell performance, cost-effectiveness, and durability. Catalysts are a major cost driver and a current focus area to accelerate the commercialization of fuel cells under development. Catalysts with reduced platinum group metal (PGM) loading, increased activity and durability, and lowering overall fuel cell costs could be the key considerations for the potential fuel cell developers.**



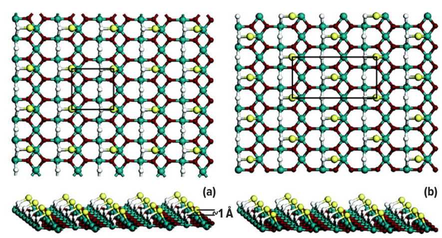

**Alia, et. al., Platinum-Coated Nickel Nanowires as Oxygen-Reducing Eletrocatalysts. *ACS Catalysis* 2014, 4, 1114**

## KEY TECHNICAL ADVANCES

- A new class of oxygen-reduction electrocatalysts offers high activity and very low noble metal content. They consist of Pt monolayers deposited on the surfaces of carbon-supported nonnoble metal–noble metal core–shell nanoparticles. The mass activity of three Pt monolayer electrocatalysts was investigated, viz., Pt/Au/Ni, Pt/Pd/Co, and Pt/Pt/Co. Each exhibited mass activity more than an order of magnitude higher than that of a state-of-the-art commercial Pt/C electrocatalyst. This custom nanoparticle design sets new standards for fuel cell cost and efficiency, with high potential for other platinum-based reactions.
- A method is developed for using platinum-metal oxide composites into the oxygen-reducing cathode of a fuel cell. The platinum-metal oxide composites are resistant to oxidation and dissolution in oxygen-reducing cathodes which improves the stability and efficiency of the fuel cell significantly.
- A new class of nanosegregated platinum multi-metallic catalysts are developed that are not only compositionally stable but also exhibit enhanced catalytic properties. The surface layers of Pt alloyed with transition metals, such as Co, Ni, Fe, Ti, Cr, V, Zr and Mn, for example, have been constructed with selected compositions to establish advantageous electronic structures which greatly enhance the catalytic properties, particularly as used for fuel cells.
- Platinum (Pt)-coated nickel (Ni) nanowires (PtNiNWs) are synthesized by the partial spontaneous galvanic displacement of NiNWs, with a diameter of 150–250 nm and a length of 100–200 μm. Unlike other extended surface approaches, the resultant materials have yielded exceptionally high surface areas, greater than 90 $m^2 g_{Pt}^{-1}$. Studies have found that reducing the level of Pt displacement increases Pt surface area and ORR mass activity.




**Zhang, et. al., *J. Phys. Chem.* B, 2005, 109 (48), 22701**




**Vukmirovic, et. al., *J. Phys. Chem.* C, 2007, 111, 15306**

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## PARTICIPATING LABS & RESEARCH CAPABILITIES

- **BNL's** fuel cell capabilities include developing advanced platinum monolayer electrocatalysts with ultra low platinum content, electrodeposition fabrication methods for MEA, state-of-the-art NSLS-II and nanoscience (CFN) facilities for characterization of materials and devices.
- **Argonne** is running active research projects to develop new materials and support existing ones to overcome the major barriers to allow the use of fuel cell technology in a variety of applications.
- **NREL's** fuel cell research aims to lower the cost and improve the performance and durability of fuel cell technologies. Research is performed on a variety of fuel cell types including PEMFC.

## MOTIVATION, CHALLENGE, AND OPPORTUNITY

As the interest for "hydrogen-based economy" grows, the research on its major elements like hydrogen production, hydrogen storage, and energy conversion in fuel cells is expanding. Electrocatalytic oxygen reduction is the reaction at fuel cell cathodes, and it has been the focus of attention because of its slow kinetics and the need for better electrocatalysts with decreased platinum content. This IP bundle compiles valuable strategies to increase performance and durability of fuel cells while decreasing their cost. This bundle provides industry leaders with the opportunity to leverage the expertise from 3 National Labs, through one standard and convenient agreement.

## TECHNOLOGIES IN THIS BUNDLE

| TECHNOLOGY | NUMBER |
|---|---|
| Electrocatalyst for oxygen reduction with reduced platinum oxidation and dissolution rates | US 8,062,552; US 8,308,989, BNL |
| Synthesis of metal-metal oxide catalysts and electrocatalysts using a metal cation | US 7,704,918, BNL |
| Hydrogen absorption induced metal deposition on palladium and palladium-alloy particles | US 7,507,495, BNL |
| Palladium-cobalt particles as oxygen-reduction electrocatalysts | US 7,632,601, BNL |
| Electrocatalysts having gold monolayers on palladium, palladium alloy, and gold alloy core-shell nanoparticles, and uses thereof | US 7,855,021, BNL |
| Electrocatalysts having gold monolayers on platinum nanoparticles cores, and uses thereof | US 7,704,919, BNL |
| Platinum- and platinum alloy-coated palladium and palladium alloy particles and uses thereof | US 7,691,780, BNL |
| Platinum-coated nickel nanowires as oxygen reducing electrocatalysts | US 20160126562A1, NREL |
| Nanosegregated surfaces as catalysts for fuel cells | US 7,871,738, ANL |
| Fuel cell electrodes | US 9,065,142, ANL |