BROOKHAVEN NATIONAL LABORATORY

Accelerating Innovation

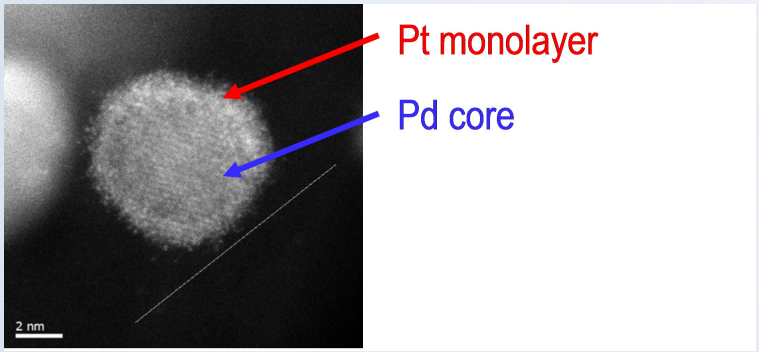
Electrocatalysts for Fuel Cells

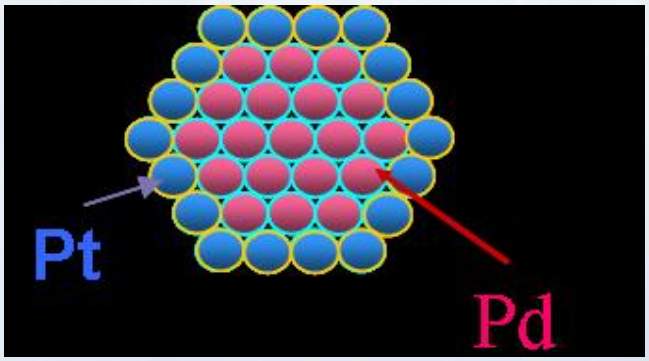
June 2012

BROOKHAVEN NATIONAL LABORATORY
U.S. DEPARTMENT OF ENERGY | Office of Science

Technology Description

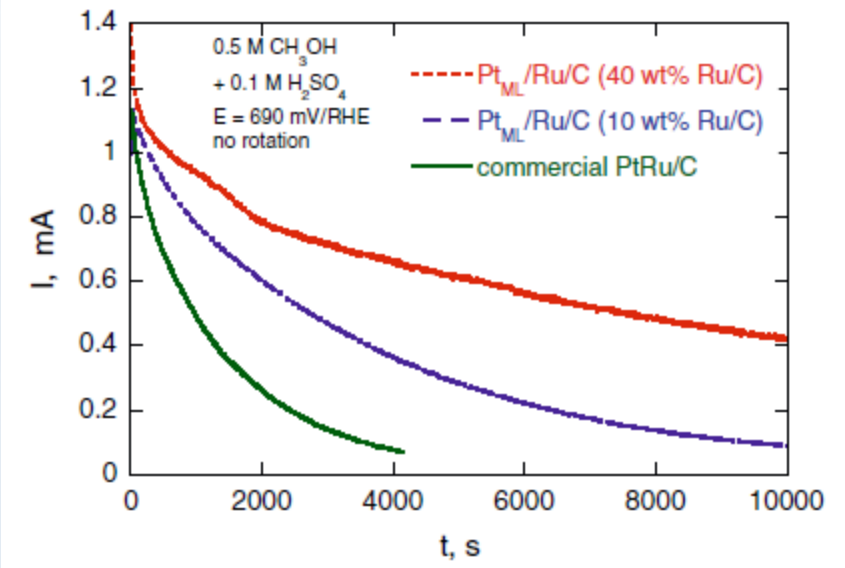
- Core-shell nanoparticles with a palladium or palladium alloy core coated by a monolayer of platinum
- All platinum atoms on surface and participate in catalysis
- Lattice contraction improves catalytic activity of platinum
- Reduction of platinum reduces overall precious metal cost





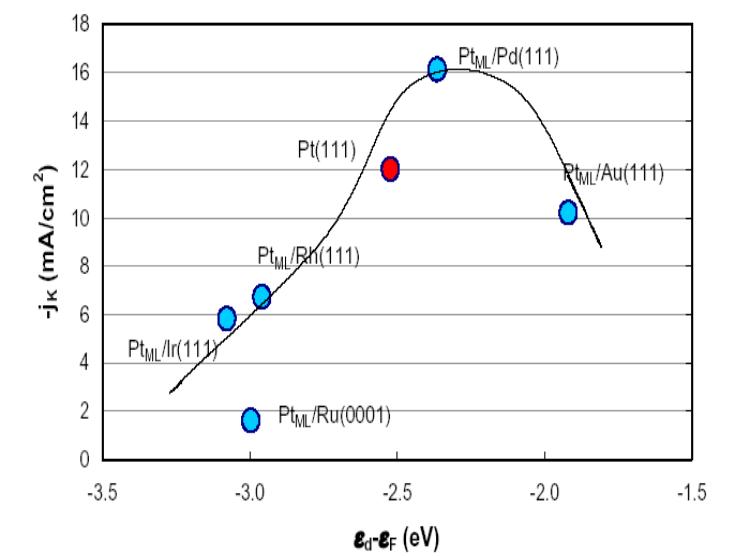
Technology Opportunity

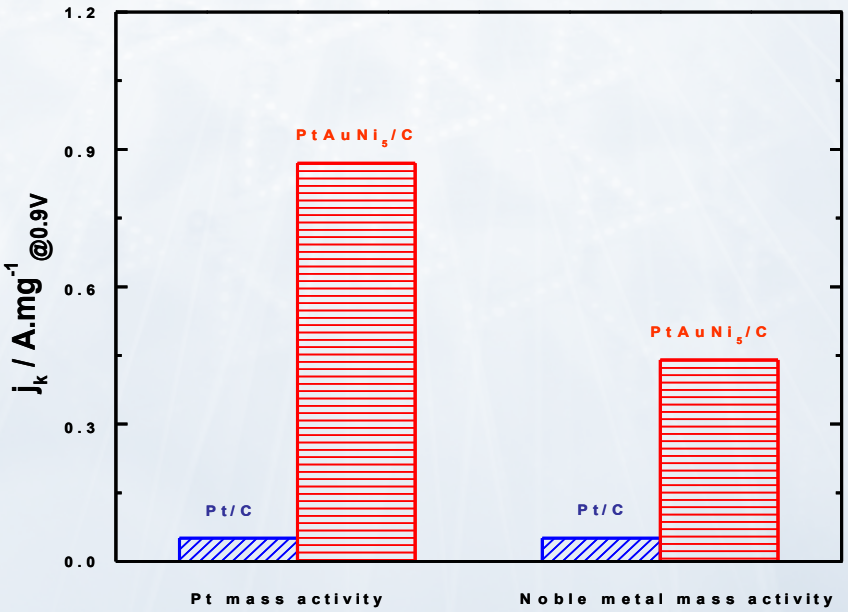
- One version of the platinum monolayer core-shell electrocatalysts is being sold in small quantities by a licensee.
- Manufacturing at commercial scale is accomplished.
- Compositions for other applications must be optimized.



Technology Leadership

- Nanoparticles of platinum *should* work better than bulk platinum in catalysis because of their higher surface area, ***but they don't***.



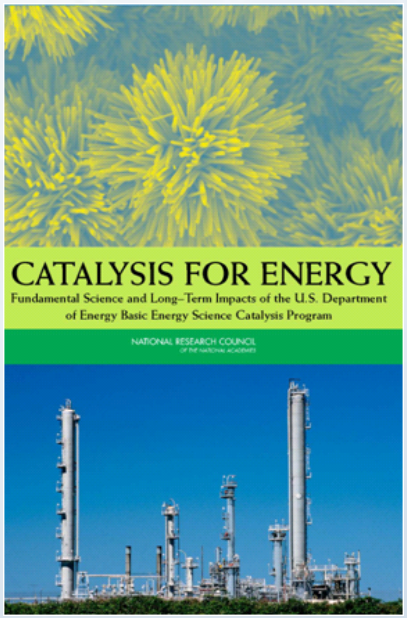


- Dr. Adzic's group was the first to achieve atomically thin layers of platinum and other platinum group metals on nanoparticles.

History: BES-EERE-Industry—Platinum Monolayer Electrocatalysts

1. Use-inspired BES research on electrochemical interfaces led to the discovery of a new class of nano-catalysts.
2. The EERE fuel cell program supported the development of the new catalysts for fuel cell applications.
3. Industrial support via CRADAs demonstrated synthesis scale up and excellent performance in fuel cell tests.

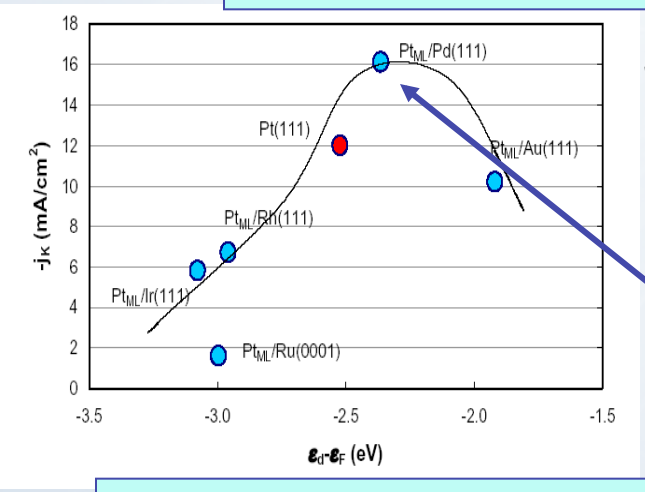
- BES user facilities – the NSLS and Center for Nanofunctional Materials (CFN) – provided key characterization capabilities (x-ray absorption spectroscopy and advanced microscopy).
- This work was featured as one of the 10 most impactful research efforts in the NAS review of the BES Catalysis Science Program.



BES-supported research 1992-present

Fundamental studies of electrocatalysis:
Oxygen reduction reaction (ORR) – mechanism, structure/activity

Insight (2000): Platinum monolayers are promising catalysts

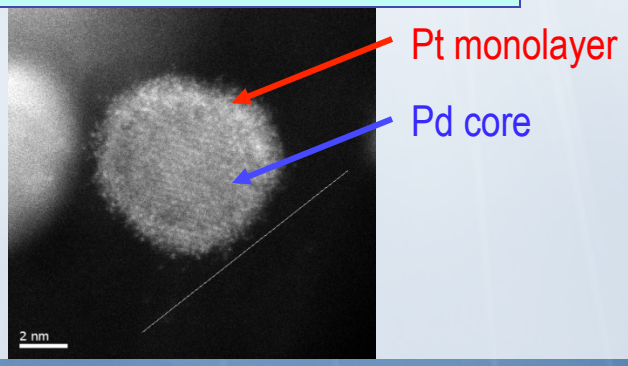


Substrate tunes catalytic activity of Pt overlayer:
- -Catalytic activity correlates to O binding energy
- -Optimum at intermediate binding: volcano plot
- -Stability can also be tuned

Pt monolayer on Pd(111) high ORR activity

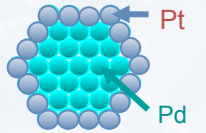
Strategy: address critical cost and stability limits of fuel cell ORR catalysts

Nanostructured core-shell electrocatalysts
- active monolayer puts all Pt atoms at interface
- substrate core tunes activity & stability

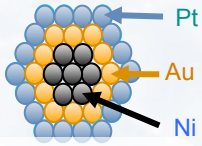


EERE-supported research 2003-present

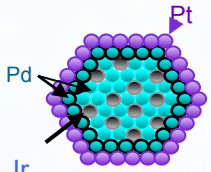
1. Several classes: tune properties & reduce cost
2. Atomic-level characterization *in situ* (XAS), *ex situ* (STEM), DFT
3. Atomic-level control syntheses fine-tune Pt-core interactions and control morphology
4. Activity, Stability, and Fuel Cell tests



Pt monolayer on Pd nanoparticles



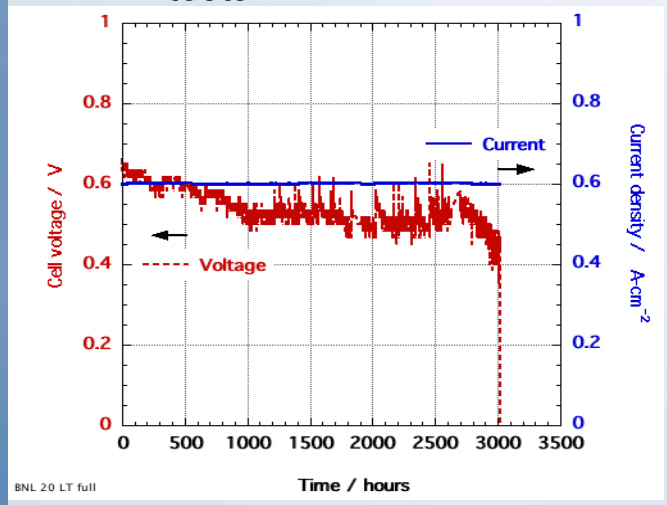
Pt on non-noble metal – noble metal core-shell;



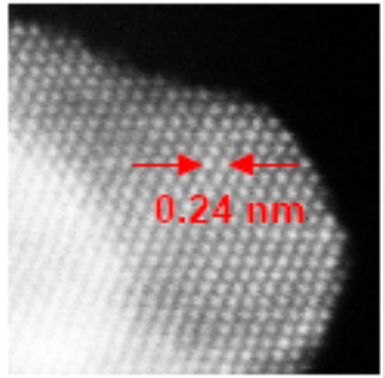
Pt on nanoparticles with interlayer of Pd

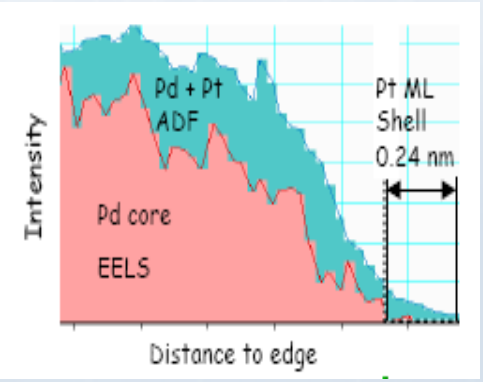
Catalytic Activity improved 5x-20x per wt Pt

Durability improved: multiple thousand hours in LANL tests



Characterization: atomic imaging of one monolayer of Pt shell on Pd-core nanoparticles using STEM/EELS at Center for Functional Nanomaterials





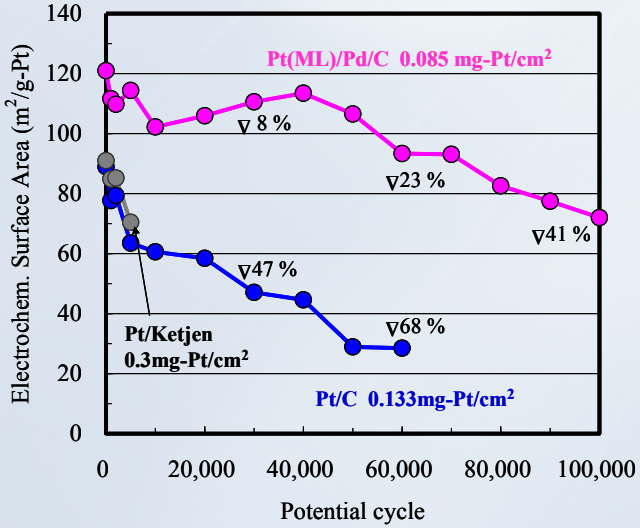
CRADAs with industry 2005-present

Scale-up, fuel cell testing: Toyota, GM, UTC Fuel Cells, Battelle

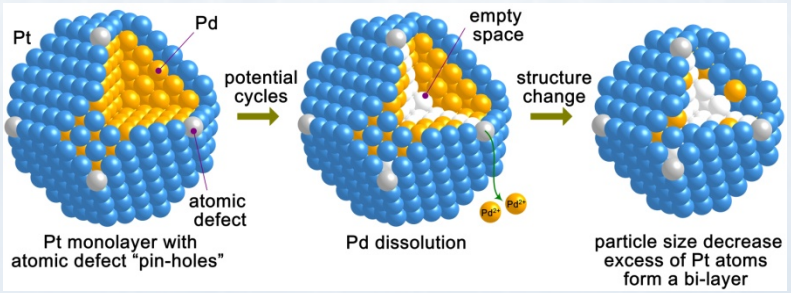
1. Demonstrate efficient, reproducible synthesis of gram quantities of Pt_{ML}
2. Fuel cell tests, performance, stability, potential cycling

Synthesis: e.g., Demonstrate scale-up to 50 gram batches of high-activity nanostructured core-shell electrocatalysts (with Toyota).

Performance: High activity, improved stability in MEA-level cycling. Scale-up will enable full fuel cell stack testing.



Understand improved stability: Evidence that Pd core acts as 'sacrificial electrode' for Pt shell.



Status: Core-shell nanocatalysts are currently promising route to PEM fuel cell commercialization.

Applications – Target Customers – Current Practice

Application Description	Target Customers	Current Practice
Fuel Cells – Oxygen Reduction	Catalyst manufacturers	Platinum on high surface area carbon
Fuel Cells – Fuel Oxidation	Catalyst manufacturers	Platinum on high surface area carbon
Hydrolyzers – Hydrogen Evolution	Catalyst manufacturers Hydrolyzer manufacturers	Platinum on high surface area carbon
Other heterogeneous catalysis	Catalyst manufacturers Petrochemical companies	Platinum on supports

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