Highly Dispersed Metal Catalyst

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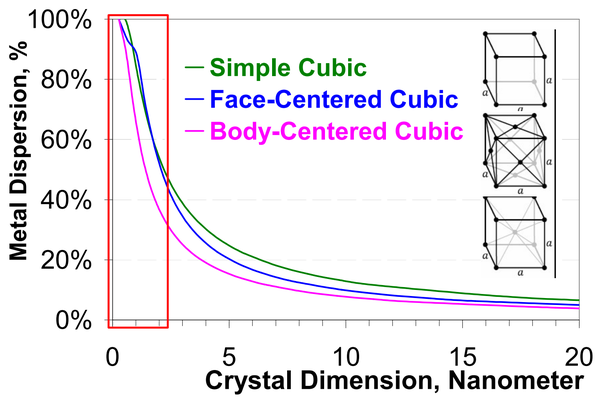
Technology

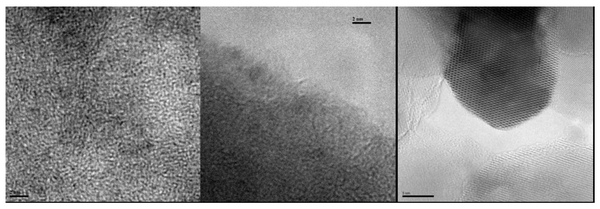
Sub-nano technology to the atomic precision

•Nanotechnology is very powerful for dramatically novel materials
•In catalysis only surface layer of atoms matters. Additional 10X - 100X improvement potential if every atom is active for catalysis, instead of being stack on top of each other
•Corner and edge atoms are more active, providing additional room to improve
•Use proprietary probe molecule technique to determine Pt dispersion, rather than electron microscopic or X-ray techniques commonly used in nanotechnology research



•Even as small as 3 to 4 nm particles, only 25-35% of the Pt is active for catalysis, since only that fraction is accessible
•Current Fuel Cell metal dispersion: 0.2 - 30% range (3.5 - 500 nm)

100% Pt dispersion achieved in SRNL



•Left: black single dots in PtSn/C
•Middle: particle edge of PtSn/C
•Right: atomic resolution of TiO_2

Benchmark with commercial catalysts

Catalysts	Pt content	Pt dispersion*
BASF Pt/C (C1-40)	39.7%	6.2% (15 nm)
TKK Pt/C (TEC10E50E)	45.9%	21.7% (4.5 nm)
Aldrich Pt/C (205923)	1.0%	47.3% (2.2 nm)
PtSn/C	1.5%	90.1%
Pt/Al_2O_3	0.5%	99.3%
Activated Carbon (blank)	- - -	-0.1%
Al_2O_3 (blank)	- - -	-0.3%

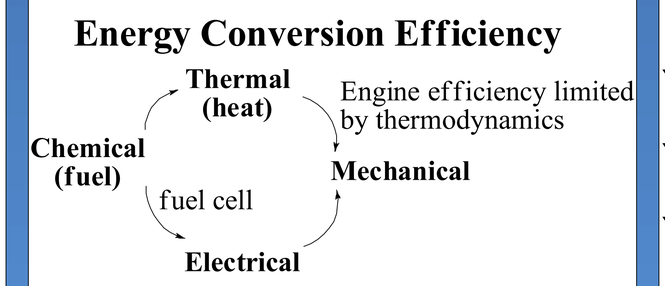
* Nanometer based on calculated value

Markets

Catalyst for fuel cell

•Market demand already exists both domestic and international, waiting for technological breakthroughs
•DOE, DoD and private sectors already invested multi-billion dollars
•DOE fuel cell funding will likely stay at $150MM/year level

Why fuel cell?



Potential customers

•Federal and local governments
•Auto makers
•Fuel cell developers

Advantages

•Fuel cell electrocatalysts frequently employ 20-50% platinum (Pt), while less than 0.5% Pt is used in industrial catalysts at 100% Pt dispersion.
•An opportunity to improve catalyst activity by 10X, using only 10% Pt (100X improvement).
• It could power a car by direct fuel cell if the electrical current density is increased by 2 to 3 magnitudes.
•Hybrid fuel cell vehicle with battery auxiliary power and regenerative braking allows a 20HP fuel cell to power an 100 HP car.

Fuel cell applications

•Vehicle market
•Stationary and portable power
•Off road applications
•Marine vessels
•Consumer electronics
•Direct Fuel Cell

Other applications

•LEL sensor
•Rechargeable Battery
•Petrochemical
•Radioactive material confinement
•Homeland Security/Nonproliferation

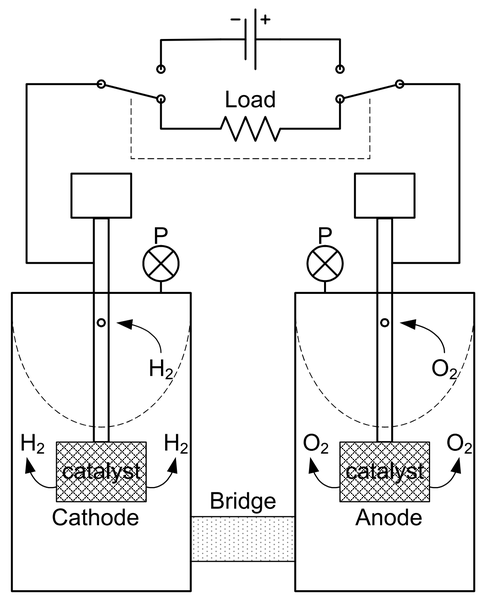
Commercial Readiness

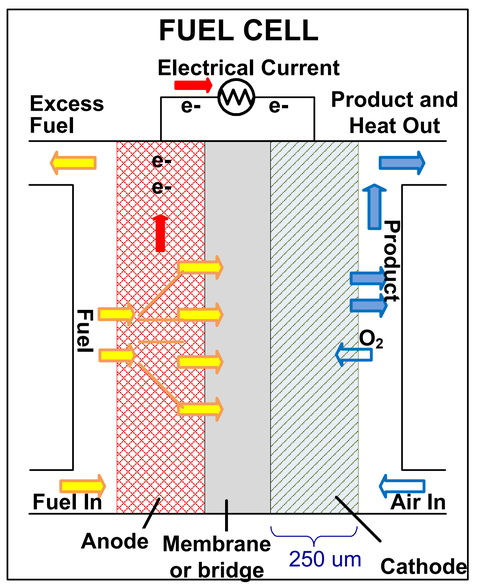
Approaches

•Gas phase reaction $H_2+O_2=H_2O$
•Electrochemistry w/o membrane
•Kinetic study to differentiate catalyst activity from mass transport
•From intrinsic activity of the catalyst active site to electrochemical power
•From Micro-Robinson-Mahoney catalyst reactor to fuel cell stack
•Scale-up is straightforward (adding stacks)
•Go/no go decision each year

Y1	Catalyst optimization	$1.5M
Y2	Activity in solution without diffusion limitations	$2.0M
Y3	Electrochemical activity	$2.0M
Y4	Build and evaluate a complete fuel cell	$2.0M
Y5	FC stack demonstration	$2.0M

Micro-Robinson-Mahoney catalyst reactor





I.P.

US Patent Application is in process by SRNL.

SRNL Technology

•100% Pt dispersion achieved
•Proven H_2/O_2 gas phase reaction
•Activity doubles availability of Pt
•To demonstrate electrochemically
•Need to prove it in a fuel cell

Significance

The expense and energy efficiency of fuel cells are limiting factors to their widespread adoption. These two factors have been difficult to overcome due to the limitations of current platinum deposition technologies. Our Highly Dispersed Metal Catalyst process will allow fuel cell manufacturers to reduce the amount of Platinum used and increase the efficiency, thereby resulting in magnitudes of improvements in both catalyst activity and cost effectiveness. Despite the perceived wisdom that 3-5 nm Pt particles are required for fuel cells, several fold increase of electrical current density was repeatedly reported over smaller Pt clusters in fuel cell applications by other researchers [1-3]. SRNL is seeking breakthrough type of advances.

1. Nature Chemistry 1, 397 - 402 (2009).
2. J. Phys. Chem. B 2004, 108, 10955.
3. Science 2009, 324, 1302-1305.

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