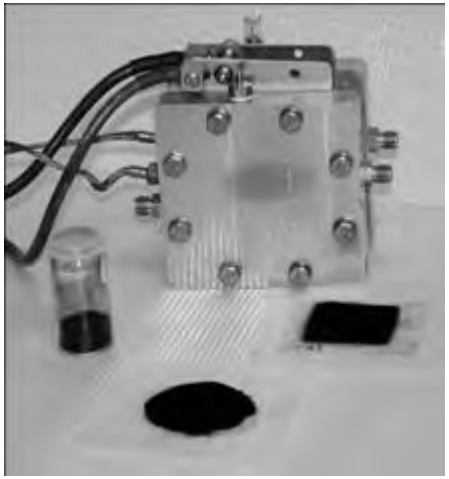
Hannover Messe 2016

PAJARITO POWDER



Engineered Carbon Supports for low precious-metal-content catalysts

Tom Stephenson, CEO & Chairman
Dr. Barr Halevi, CTO & President
Dr. Alia Lubers, Catalyst Manufacturing Manager
Webb Johnson, Director of Business Development

Copyright 2016 Pajarito Powder, LLC. Proprietary

Pajarito Powder Mission

PAJARITO POWDER

Fundamentally Change the Economics of Fuel Cell Catalysts

Key Dates:

- ***Company Started: January, 2012***
- ***Commercial Launch: February, 2014***

Copyright 2016 Pajarito Powder, LLC. Proprietary

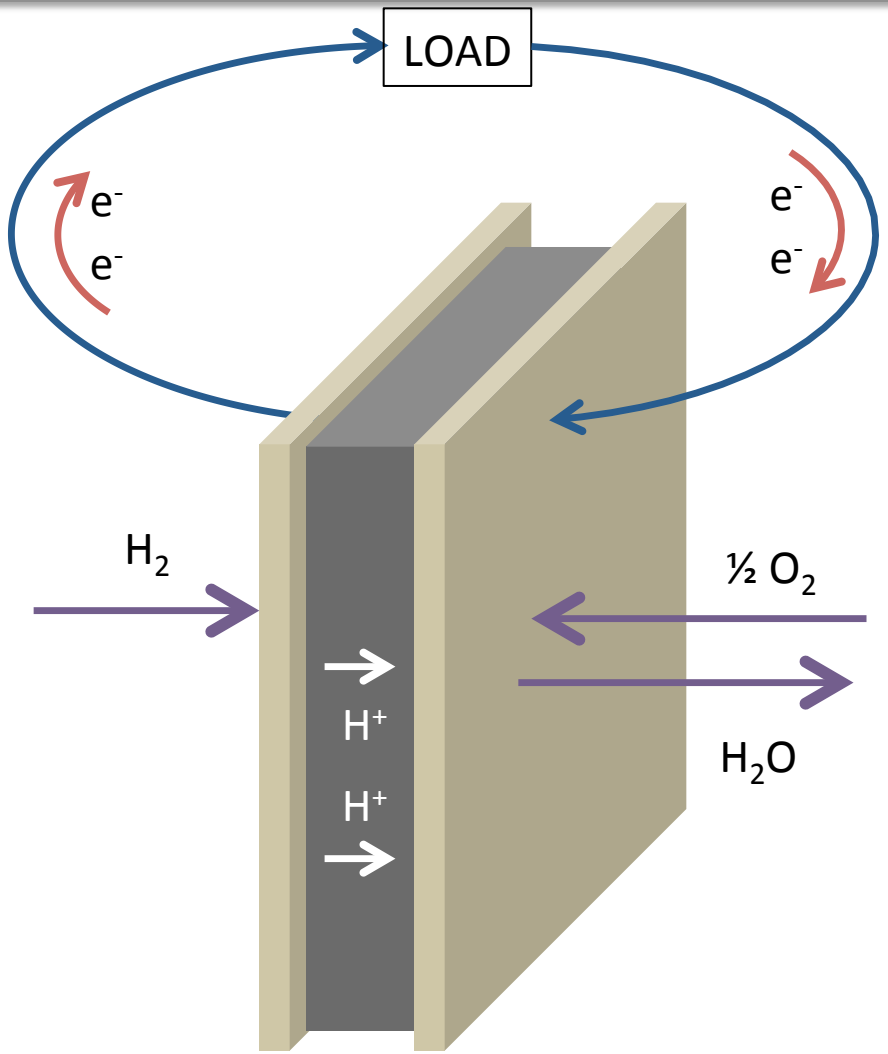
Strong and Growing IP

PAJARITO POWDER

- Multiple Intellectual Property Sources
  - Los Alamos National Laboratory
  - University of New Mexico
  - INRS
  - Northeastern University
  - "Native" intellectual property
- Partners on U.S. Government Grants
  - U.S. DOE ARPA-E Grant (prime)
  - U.S. DOE "Incubator" grants (sub-awardee)
  - SBIR grant (sub-awardee)

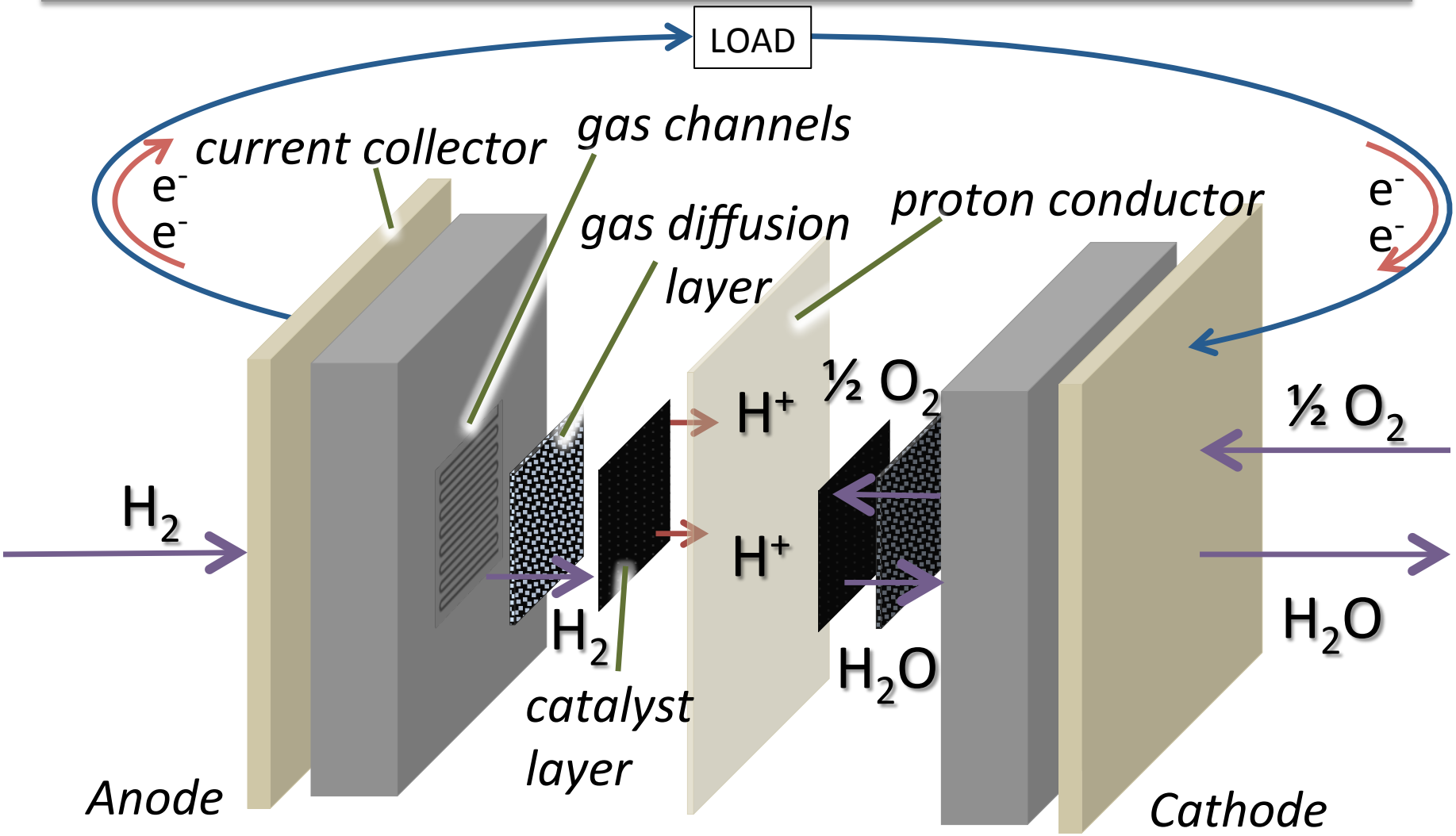
Copyright 2016 Pajarito Powder, LLC. Proprietary

PEM Fuel Cell:



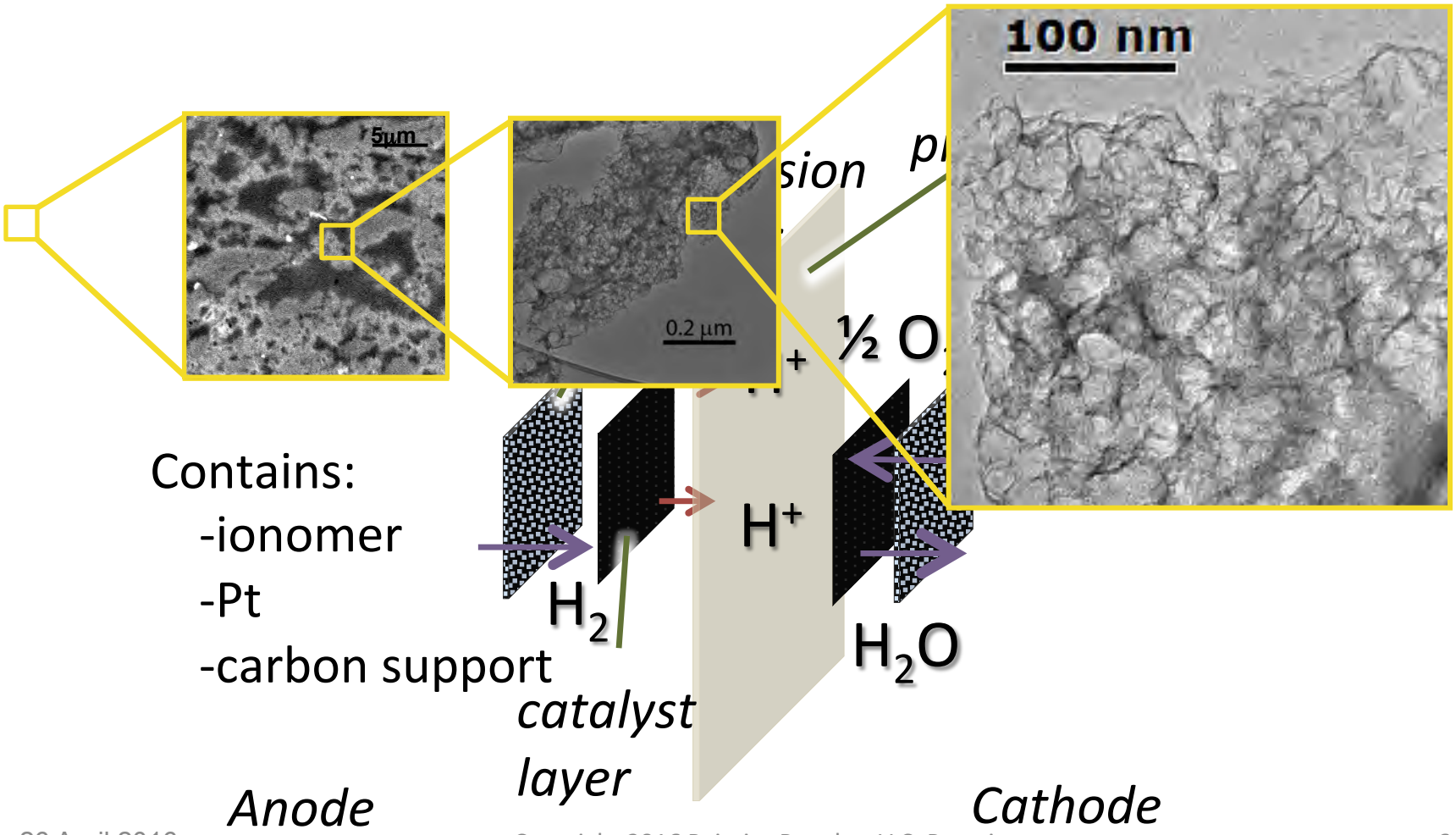
Copyright 2016 Pajarito Powder, LLC. Proprietary

PEM Fuel Cell: Components



Copyright 2016 Pajarito Powder, LLC. Proprietary

Membrane Electrode Assembly



Contains:
- -ionomer
- -Pt
- -carbon support

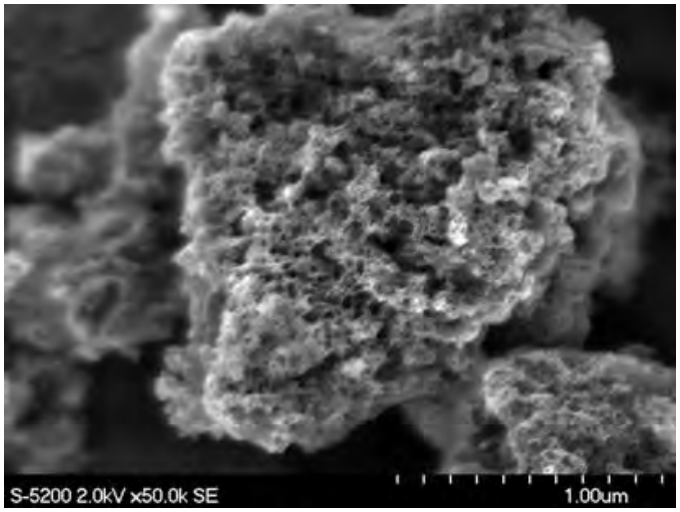
Copyright 2016 Pajarito Powder, LLC. Proprietary

Product Offering: PHC-3000

PAJARITO POWDER

Engineered Carbon Support (ECS)

- For low-loaded Pt catalysts
- High corrosion resistance (durability) & dispersion of Pt
- *Near-term solution for improved End of Life performance*



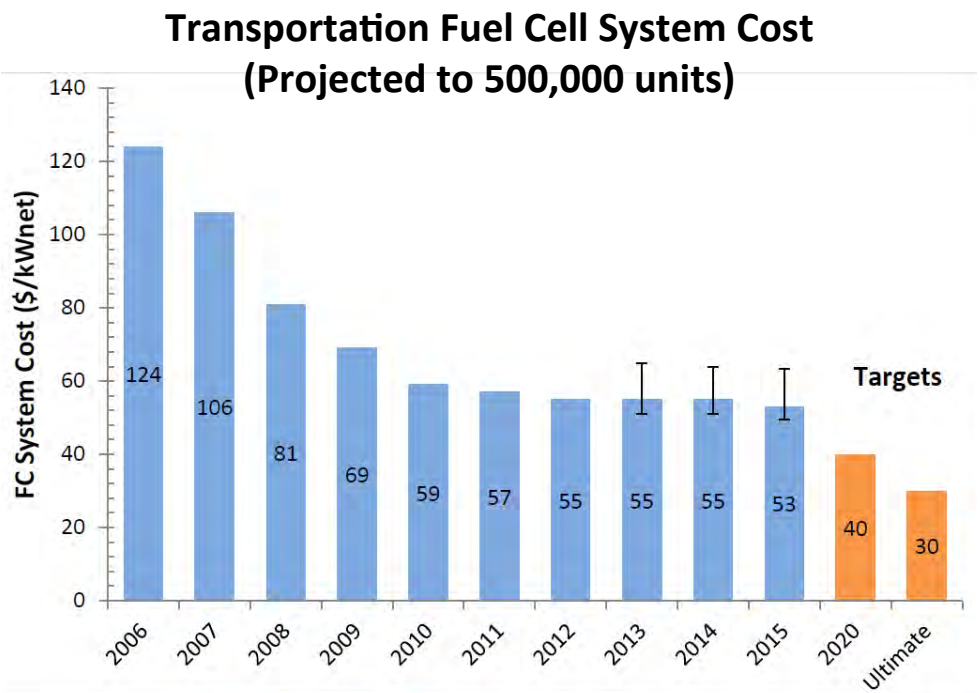
Copyright 2016 Pajarito Powder, LLC. Proprietary

Achieving Cost Targets

PAJARITO POWDER

"Top-down" approach

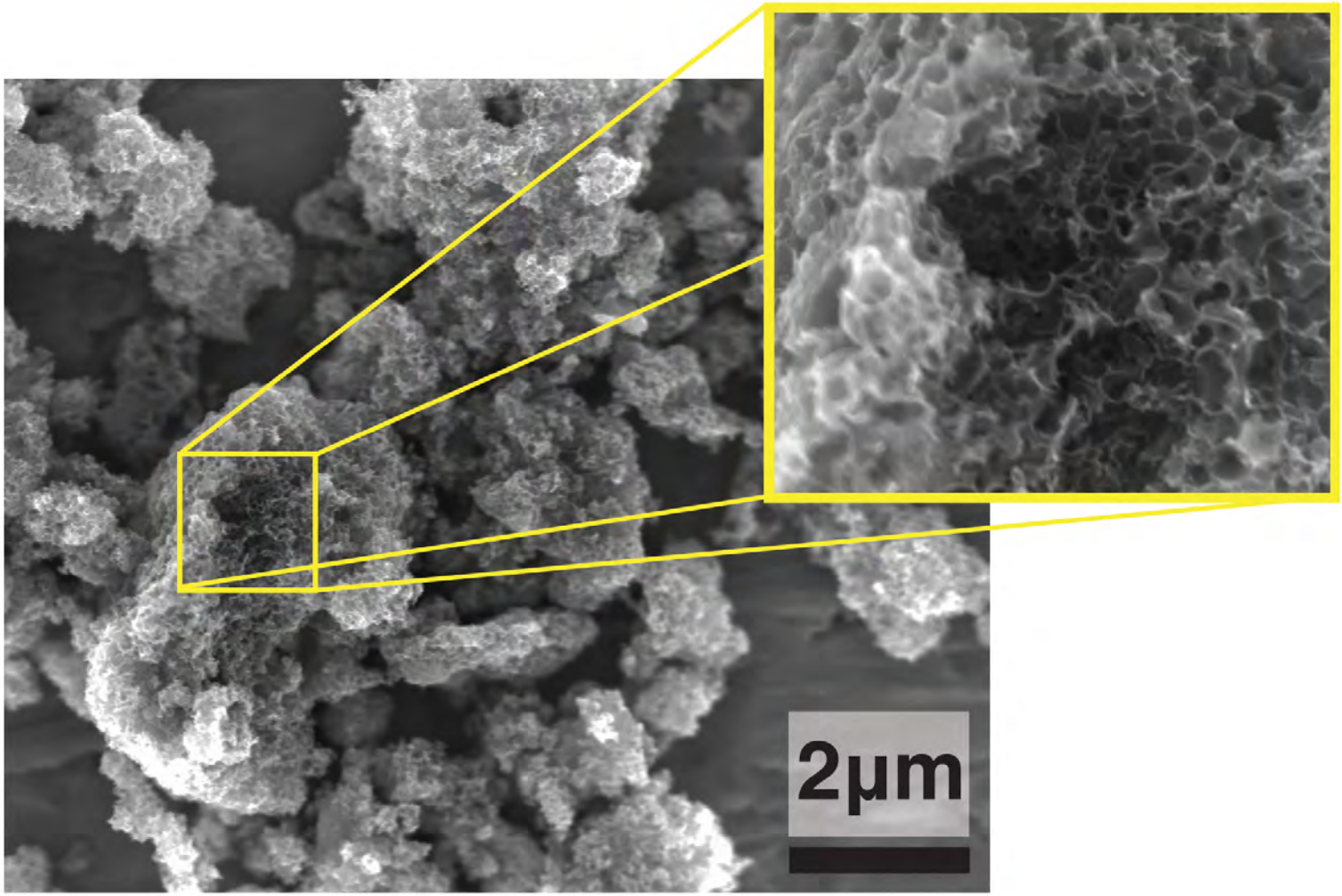
- Less Pt
- Higher durability
- Targeted morphology
  - Particle size and
  - Pore size & distribution
  - Surface area
  - Surface functionalization



http://energy.gov/eere/fuelcells/fuel-cell-technologies-office-accomplishments-and-progress

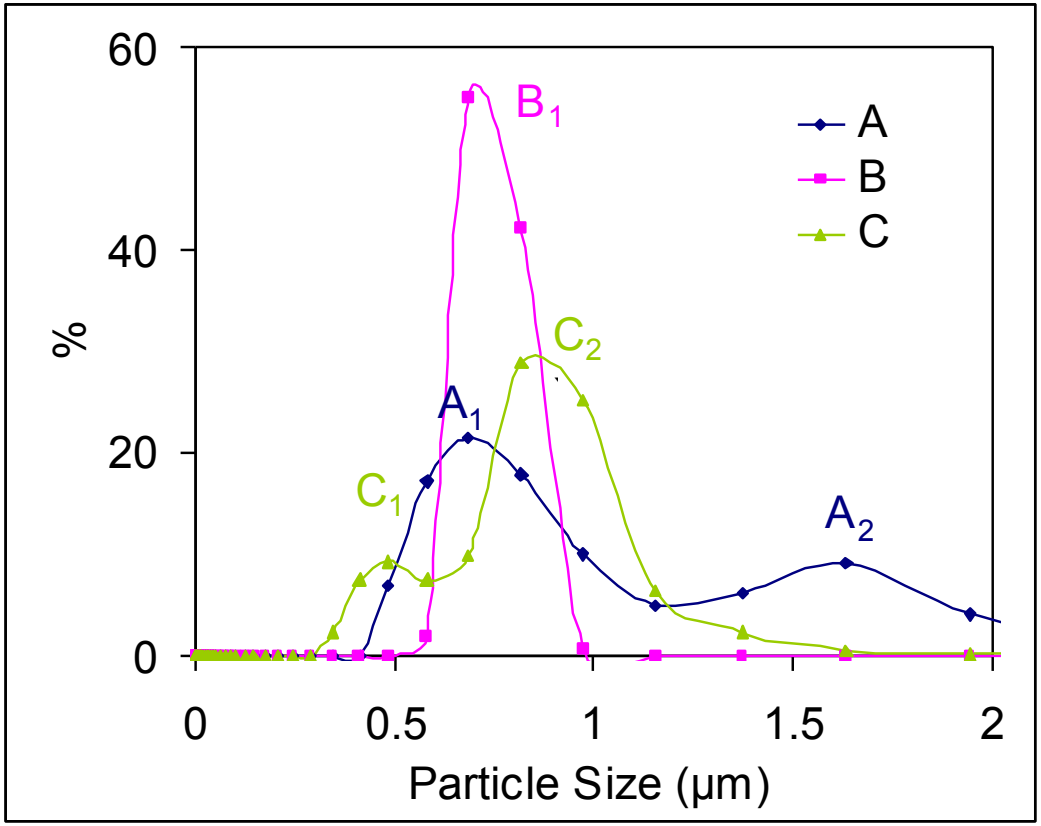
Copyright 2016 Pajarito Powder, LLC. Proprietary

Manufacturing Approach



Copyright 2016 Pajarito Powder, LLC. Proprietary

Tailored Particle Size

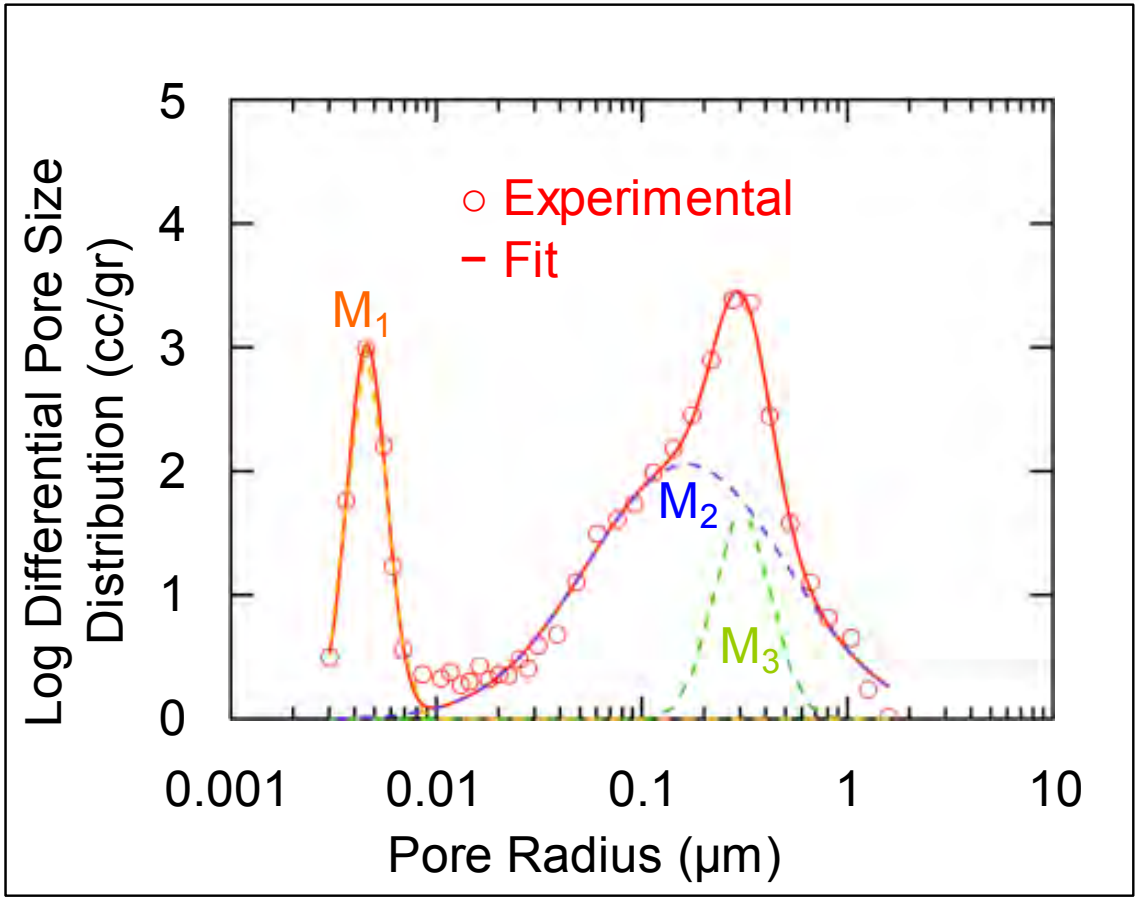


Microtrack Nanotrac 250
High shear mixing, 15min
of 50mg$_{cat}$/5mL Isopropyl alcohol
1:10,2:10,4:10 Wcat:WIPA

Particle size control for electrode porosity tailoring

Copyright 2016 Pajarito Powder, LLC. Proprietary

Pore Size Control

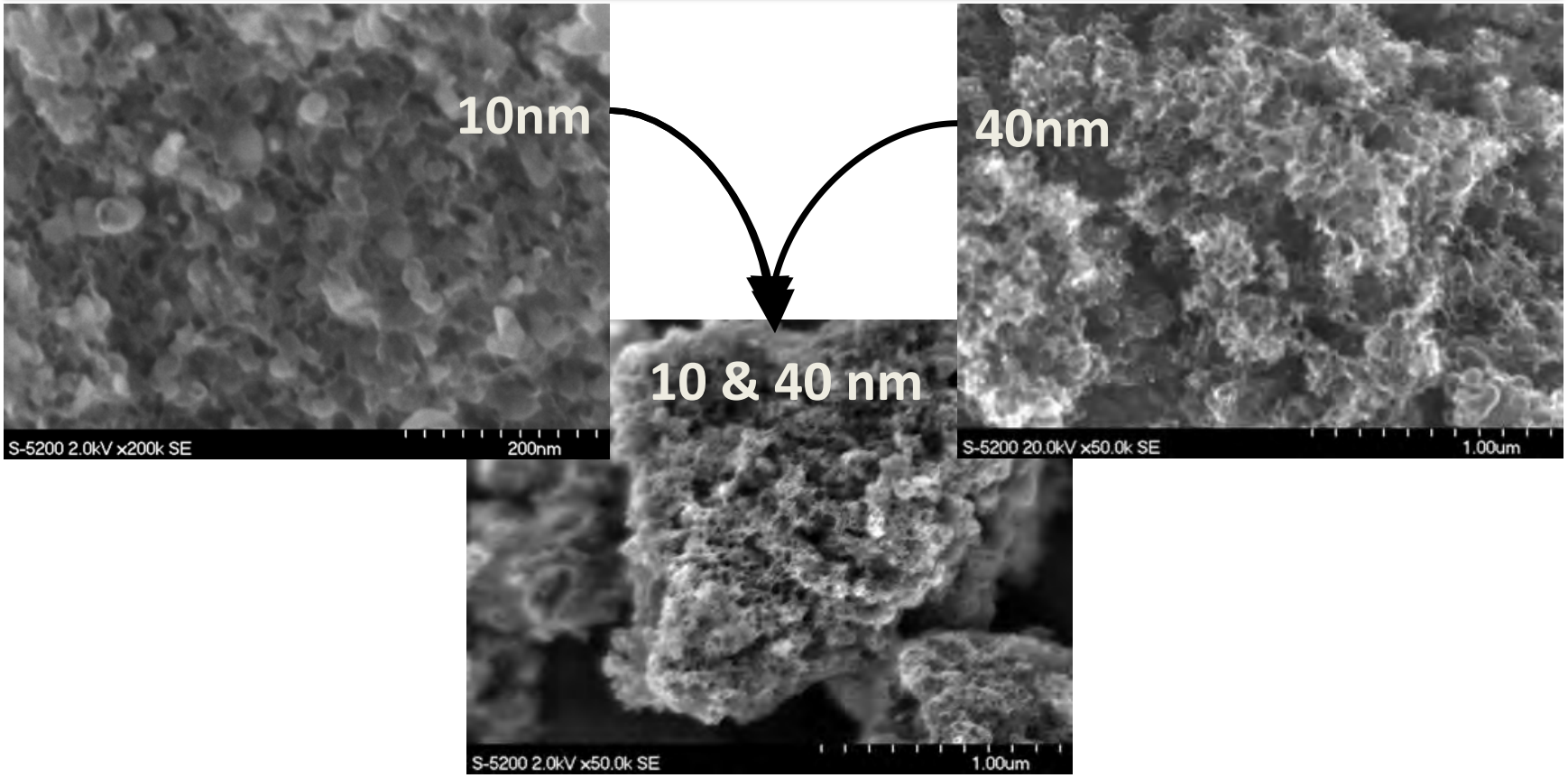


Pore size control established (BJH method)

Copyright 2016 Pajarito Powder, LLC. Proprietary

Tailored Porosity Control

PAJARITO POWDER

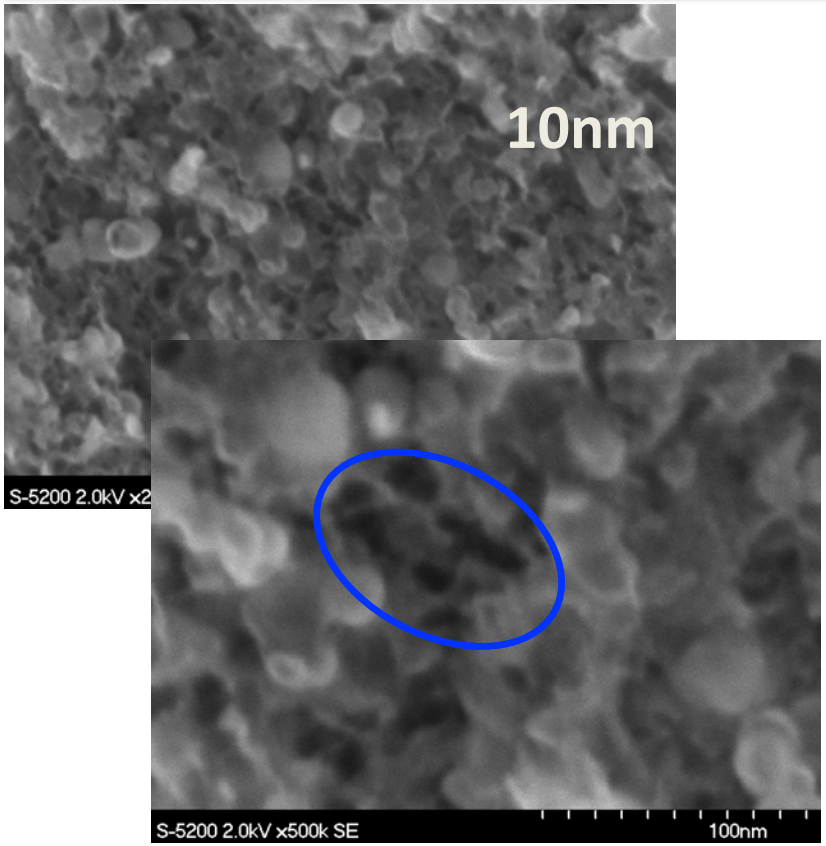


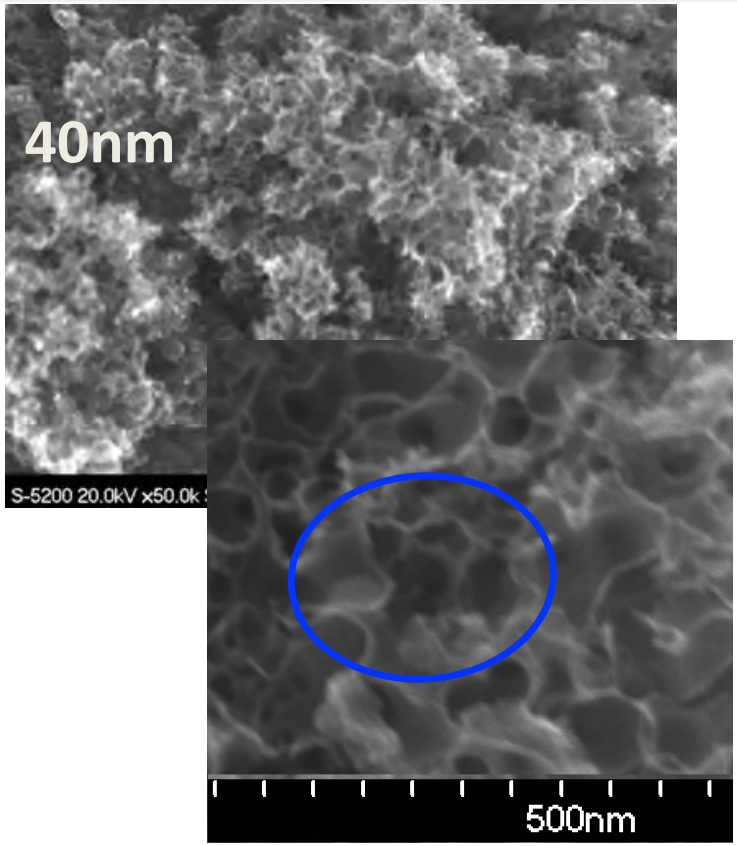
Tailored pore size and distribution achieved, 5-50nm and 200-700m²/gr.
Highly graphitized

Copyright 2016 Pajarito Powder, LLC. Proprietary

Pore Inter-connectivity

PAJARITO POWDER





Pore interconnectivity is evident by SEM, and implied by surface area and pore size distribution

Copyright 2016 Pajarito Powder, LLC. Proprietary

Platinized PHC-3000

PAJARITO POWDER

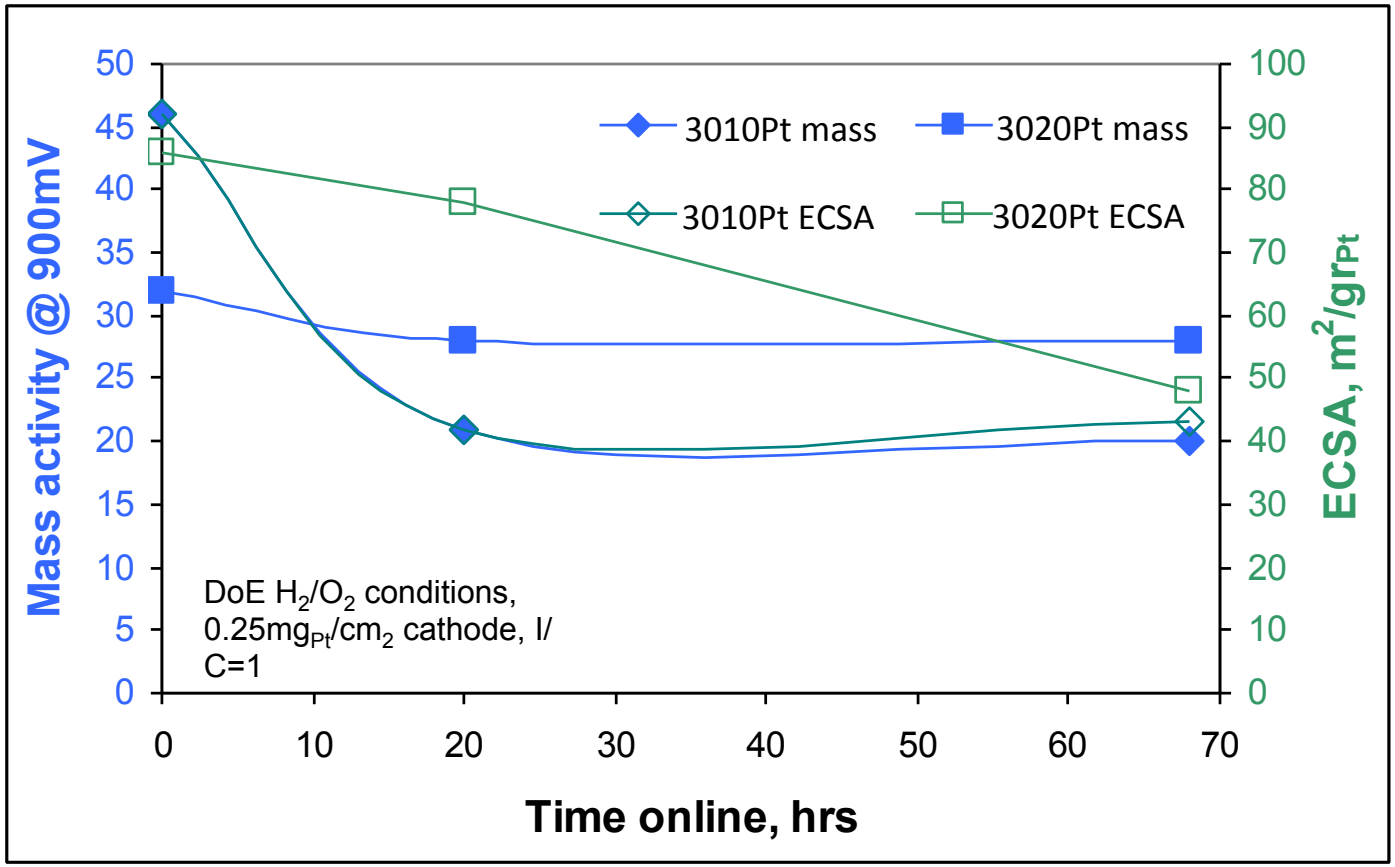
Catalyst Name	3010Pt	3020Pt
Support name	PHC3010	PHC3020
BET Surface Area (m^2/g)	280	200
Pt Surface Area[1] (m^2/g_{Pt})	220	180
Pt particle size[2] (nm)	<2.0	2.6
Pt content[3] (wt%)	28	26
Avg particle size (μm)	0.5	0.5

[1] CO stripping [2] XRD [3] XRF (more graphitized)

Platinized samples made and tested: Sample 2 is graphitized version of Sample 1

Copyright 2016 Pajarito Powder, LLC. Proprietary

1.2V Hold Testing



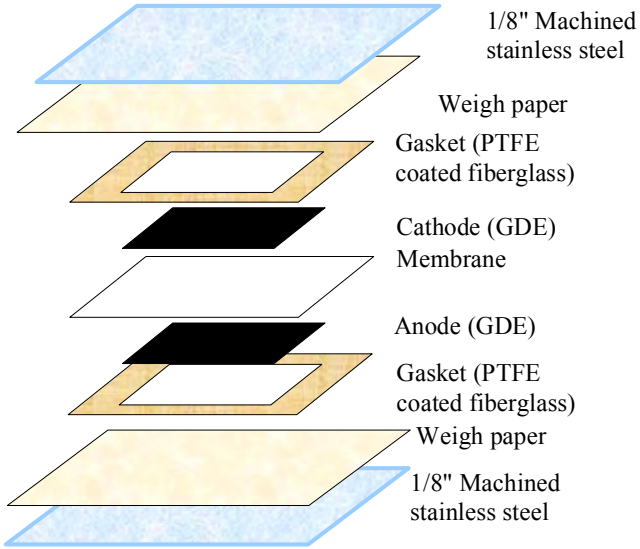
Platinized samples made and tested under 1.2V Hold. 3020Pt EOL is best.

Copyright 2016 Pajarito Powder, LLC. Proprietary

MEA Fabrication

IKA T-18 19mm stator
high shear mixer
2-5wt% solids Ink

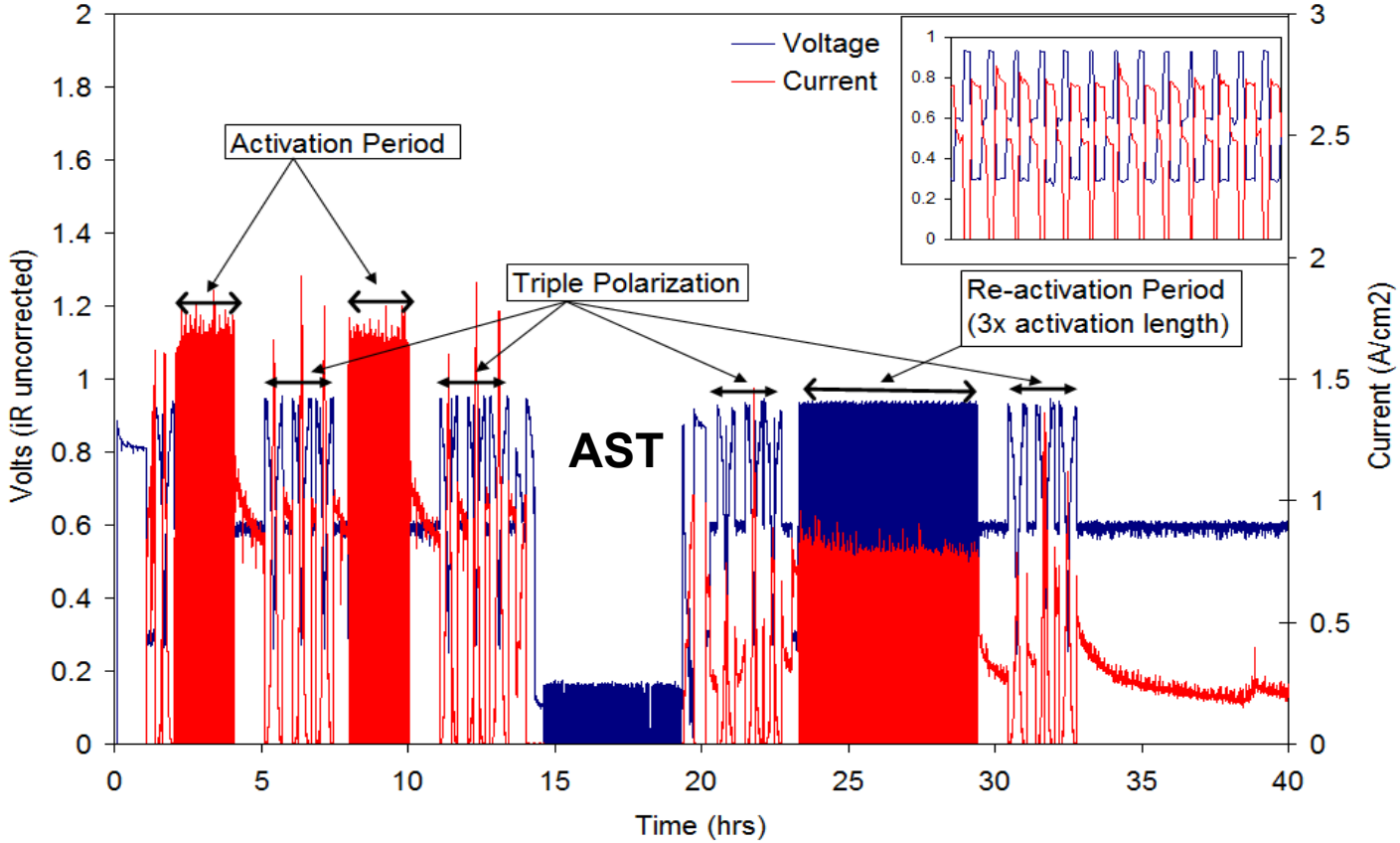
Sonitek ExactCoat
25kHz sonic nozzle
2-200μgr/cm²/pass



Carver 3860
heated press
~6+ minutes
131°C+
75psi for 25cm²
60psi for 50cm²

Copyright 2016 Pajarito Powder, LLC. Proprietary

Carbon Corrosion Testing

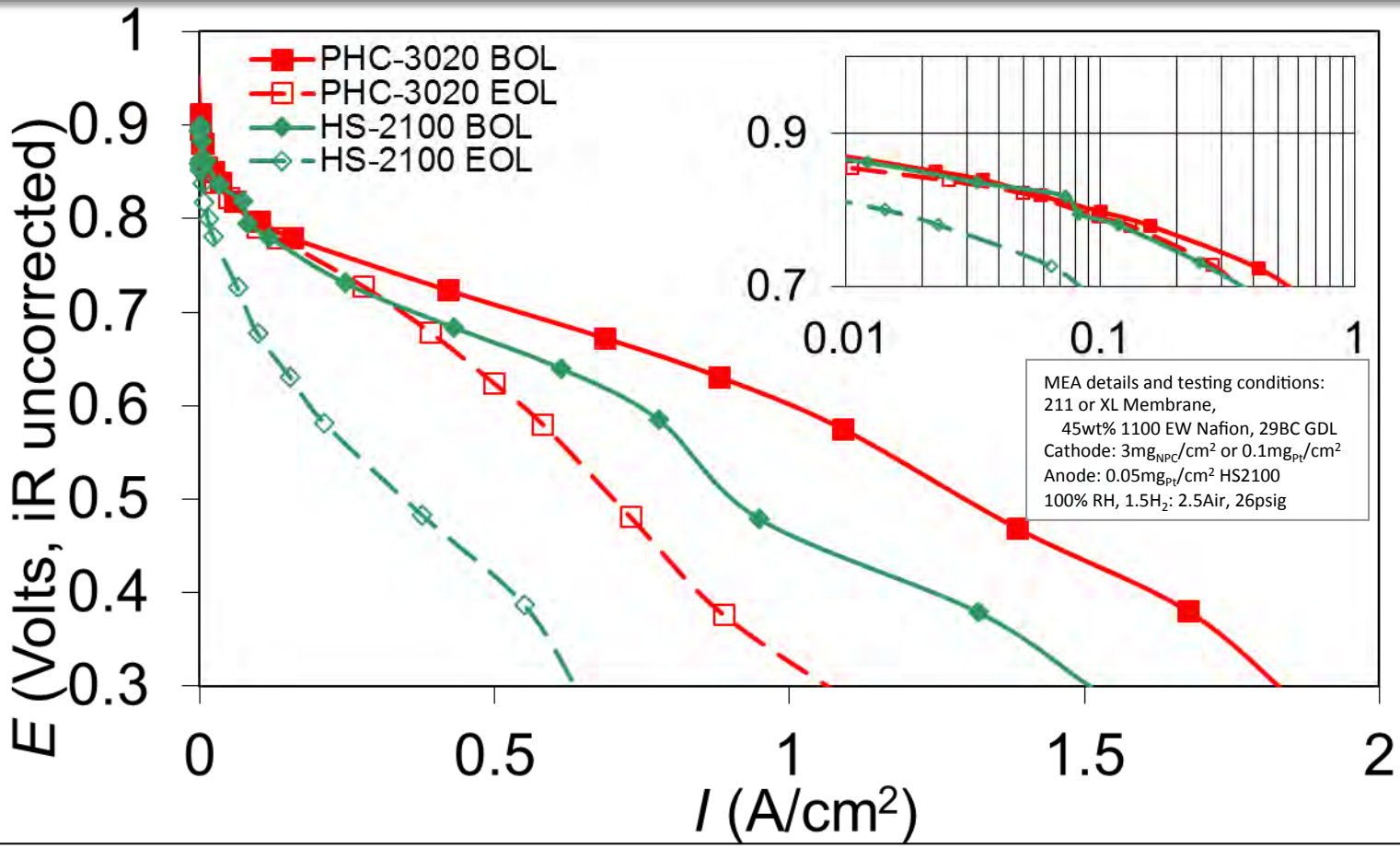


1-1.5V, 5000 cycle Start-Up/Shut-Down test procedure

Copyright 2016 Pajarito Powder, LLC. Proprietary

Carbon Corrosion Testing

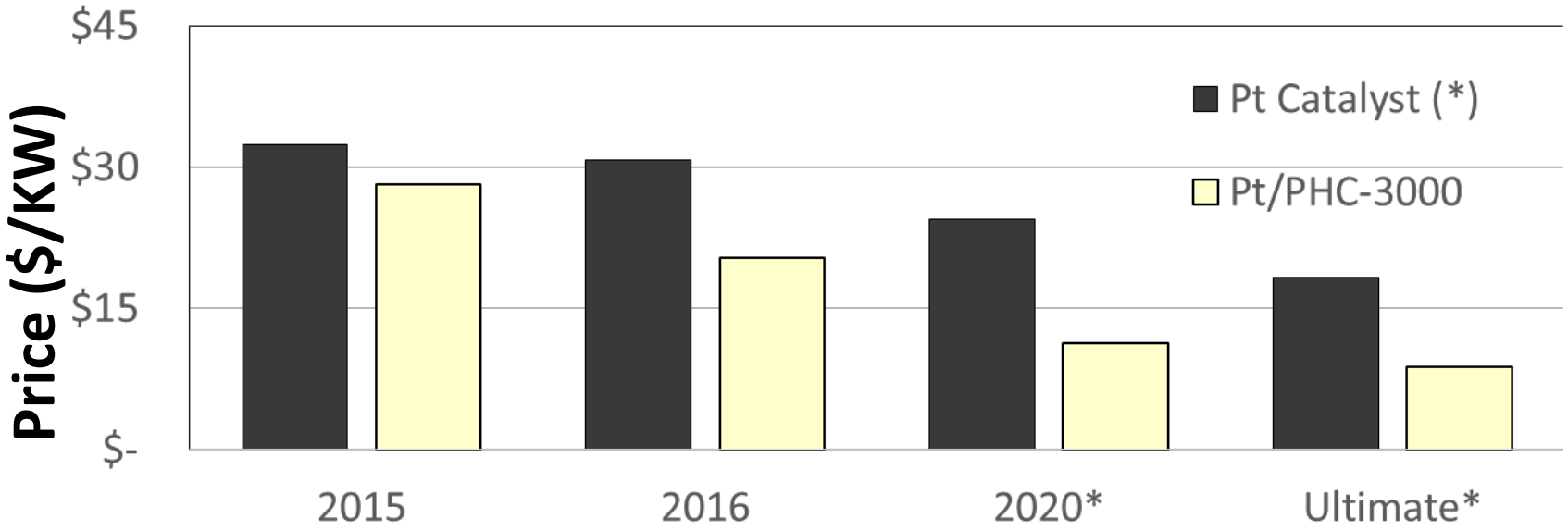
PAJARITO POWDER



OCV and shape of curve show need for improved electrode construction
Excellent BOL and durability compared to commercial non-graphitized

Copyright 2016 Pajarito Powder, LLC. Proprietary

High Benefit/Price at Scale



Capacity (Kg/Mo.)	10	100	1,000	10,000
Price ($/Gram)	$10	$3	$1.20	$0.75

2015-2016 cost savings achieved at purely through bulk purchases of raw materials

(*) From DOE "Fuel Cell System Cost – 2015"; Pt price fixed at 2015 levels

Copyright 2016 Pajarito Powder, LLC. Proprietary

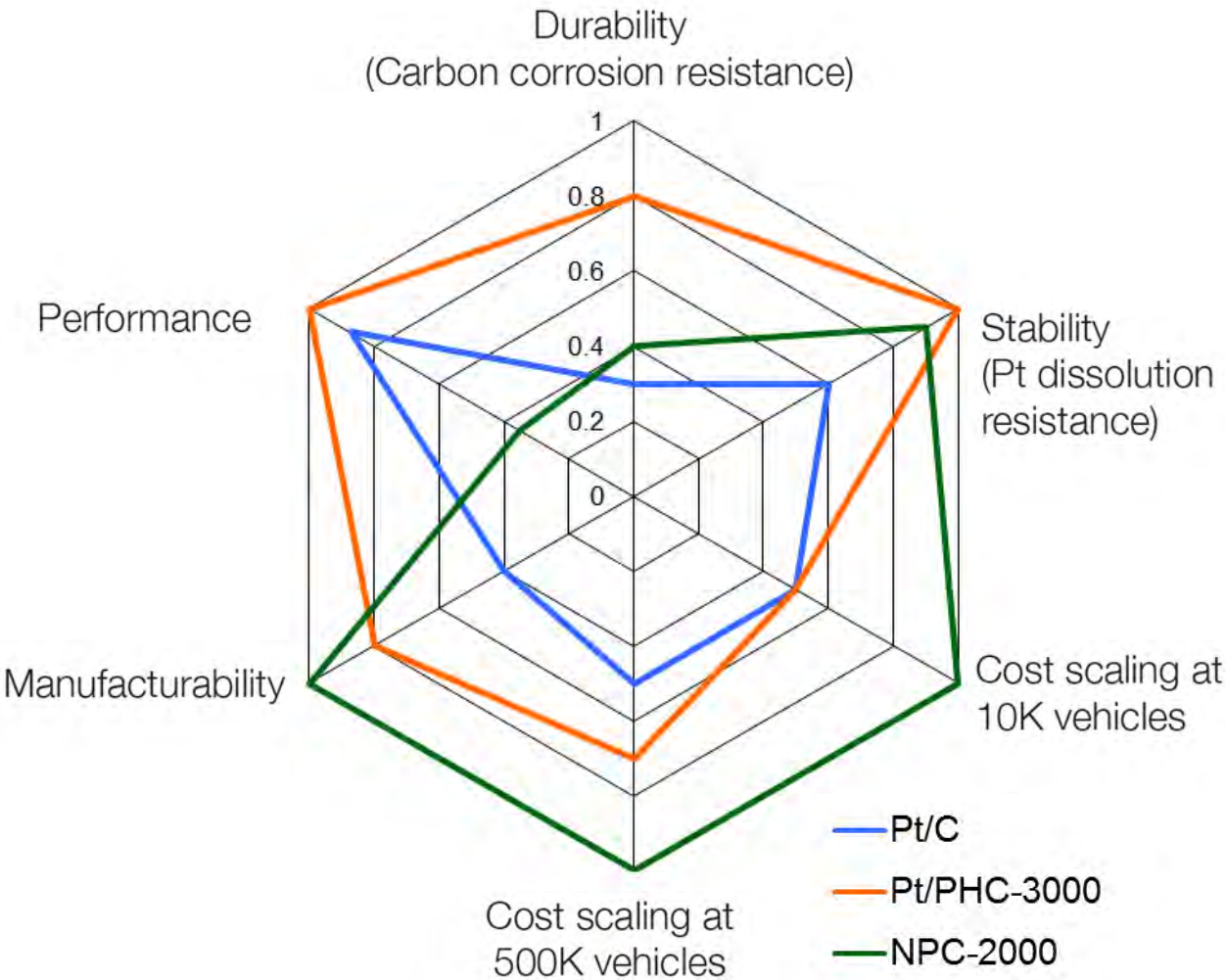
Pajarito Product Offerings

PAJARITO POWDER

- NPC-2000
  - PGM-free cathode catalyst
  - Customizable formulations
  - *Ultimate solution for future generation vehicles*
  - ***Customer feedback and joint development***
- PHC-3000
  - Catalyst support for low-loaded Pt catalysts
  - High corrosion resistance (durability) & dispersion of Pt
  - *Near-term solution for improved End of Life performance*
  - ***Recruiting partners for electrode optimization***

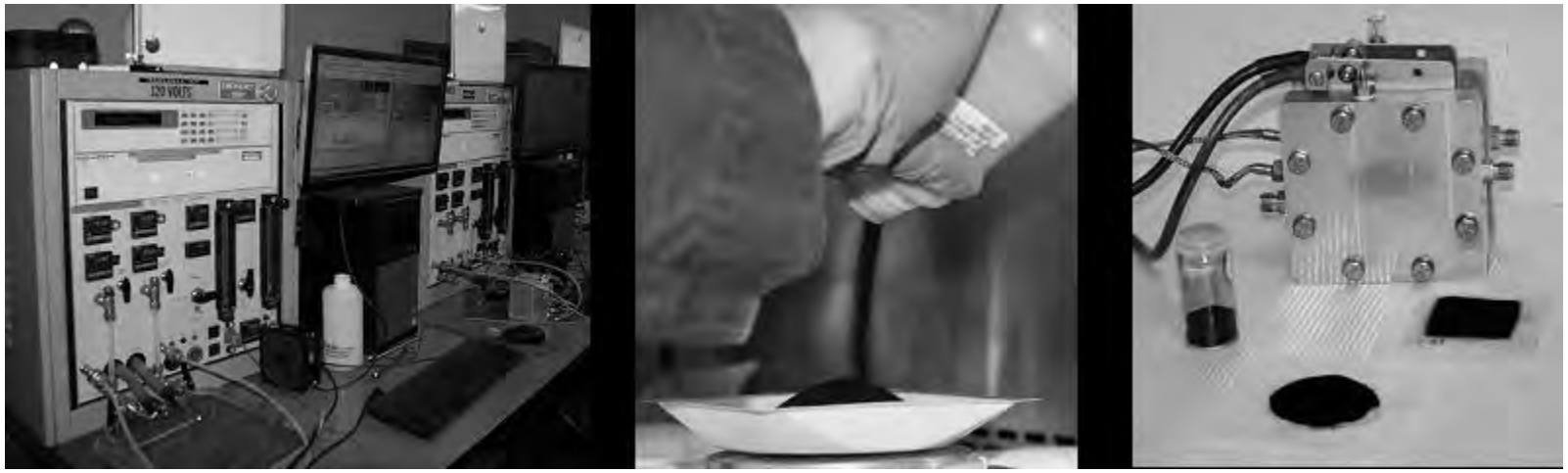
Copyright 2016 Pajarito Powder, LLC. Proprietary

Promising Solutions



Copyright 2016 Pajarito Powder, LLC. Proprietary

Questions?



Tom Stephenson, CEO & Chairman (tstephenson@pajaritopowder.com)

Barr Halevi, CTO & President (bhalevi@pajaritopowder.com)

Saburo Hori, Director of Business Development Asia (shori@pajaritopowder.com)

Webb Johnson, Director Business Development (wjohnson@pajaritopowder.com)

HYDROGEN+ FUEL CELL+BATTERIES Group Exhibit, in Hall 27, C66 at booth D31

Pajarito Powder, LLC

Albuquerque, NM 87102, USA

+1 (505) 293-5367

www.pajaritopowder.com

Copyright 2016 Pajarito Powder, LLC. Proprietary