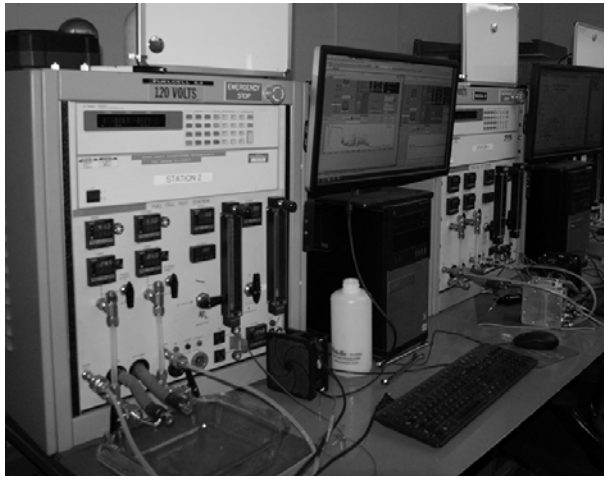
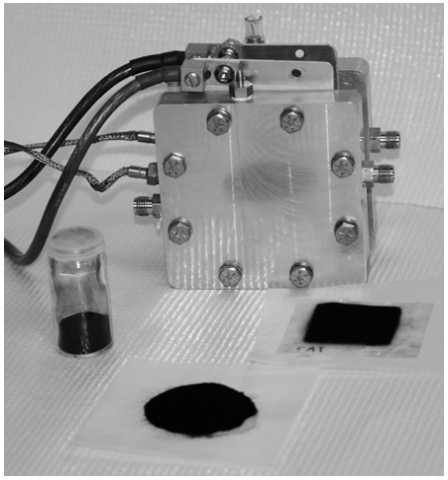
DOE CWG 6-2014

PAJARITO POWDER





Pajarito Powder

Successes and Opportunities in Scale-up of Non-PGM ORR Catalysts

PPC Purpose

PAJARITO POWDER

Create & Manufacture

<u>Affordable</u> Fuel Cell Catalysts

in Commercial Quantities

<u>Key Dates:</u>

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

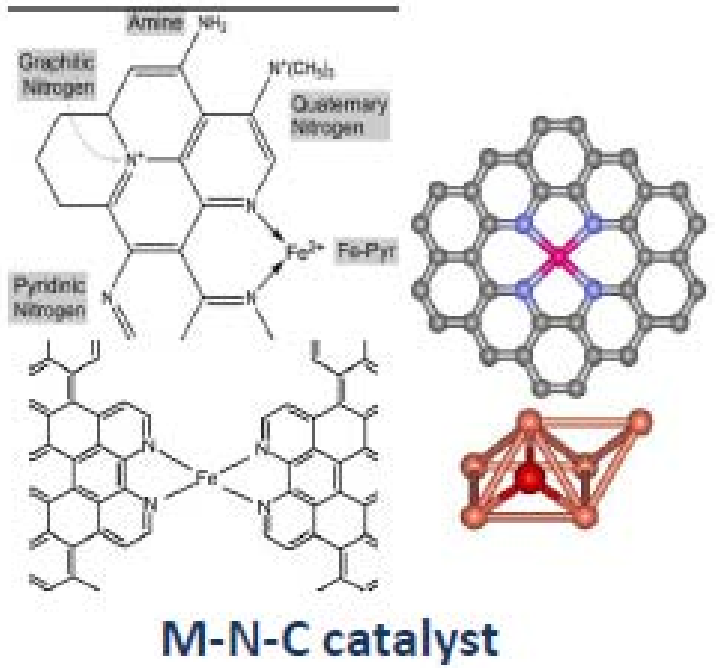
PPC Key Personnel

- **Tom Stephenson**, Chairman & CEO
  - Successful fuel cell component investor & business manager
- **Barr Halevi**, President & Chief Technology Officer
  - Manages technical team of 6
- **Alexey Serov**, Chief Scientist
  - Joint appointment with University of New Mexico
- Technical Advisory Board
  - **Piotr Zelenay**, Los Alamos National Laboratory (Chairman)
  - **Plamen Atanassov**, University of New Mexico
  - **Scott Calabrese Barton**, Michigan State University
- **Paul Short**, Board Member
  - Strategic adviser to team; served as founding CEO

Performance Criteria

PAJARITO POWDER

- Performance
  - **Stability**
  - **Durability**
- Integration
  - Must use same equipment as current PGM catalysts
- Manufacturability
  - Scalability
    - 100gr to 1 kg to 1 ton batch



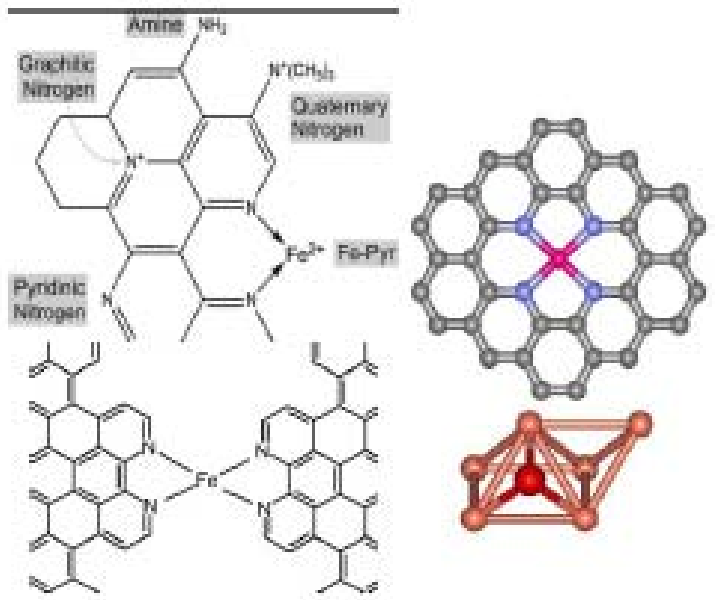
M-N-C catalyst

FC086 2013

Manufacturability

PAJARITO POWDER

- Scalability
  - Suitability to different scales
- Tunability
  - Different fuel cell applications
- **Costs**
  - Precursor costs
  - Processing costs
    - Equipment
    - Number of Steps
  - Chemical waste
  - Sensitivity to process variables



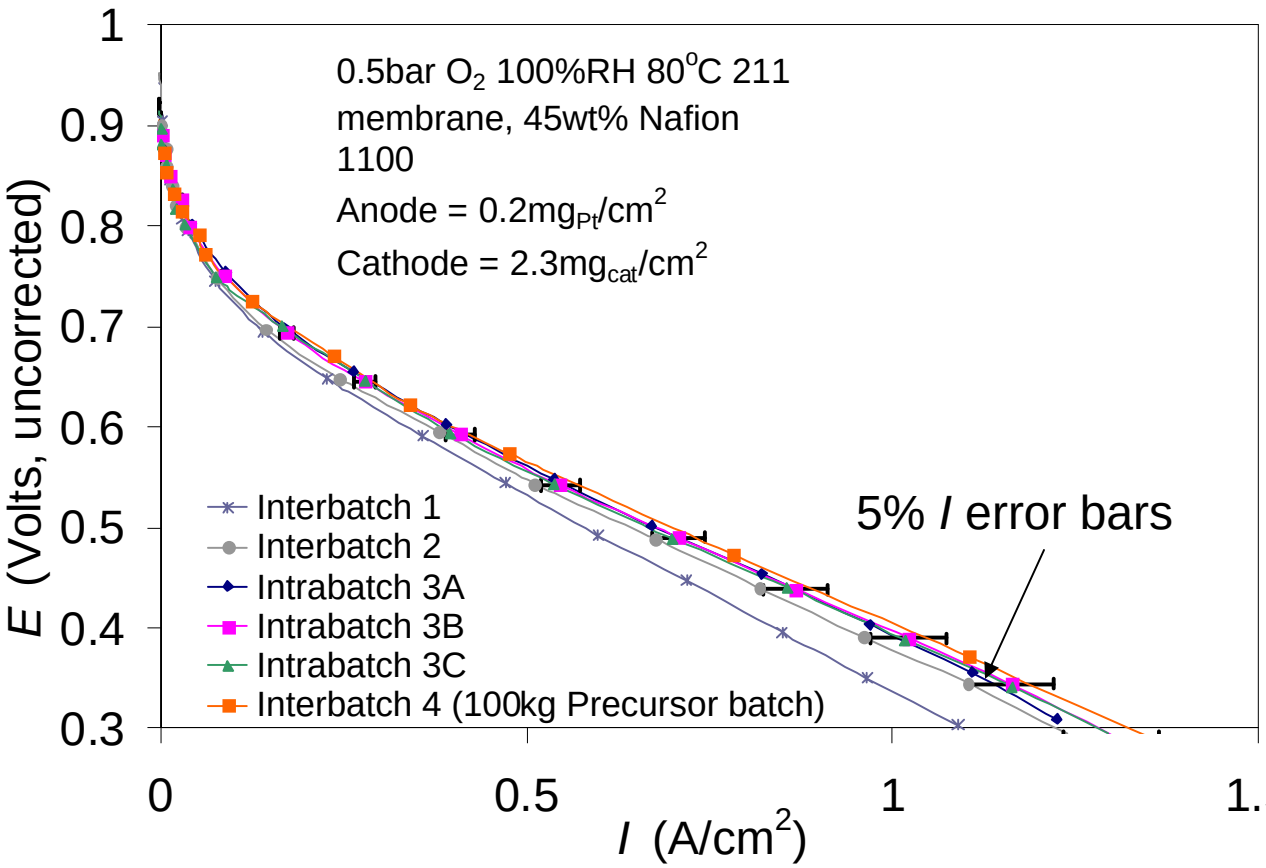
M-N-C catalyst

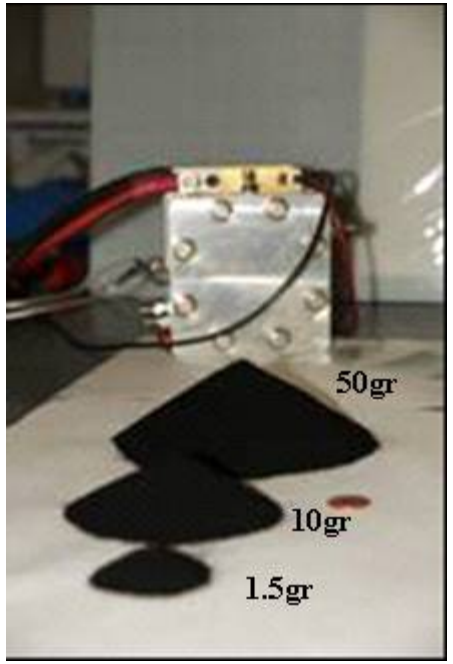
FC086 2013

Non-PGM Developers

- DOE EERE FC086
  - Northeastern University
    - Sanjeev Mukerjee
  - Michigan State University
    - Scott Calabrese-Barton
  - University of New Mexico
    - Plamen Atanassov
- DOE EERE FC107
  - LANL
    - Piotr Zelenay
- Technologies selected for scale up:
  - Michigan State University - “High Pressure Pyrolysis Method”
  - University of New Mexico - “Sacrificial Support Method”

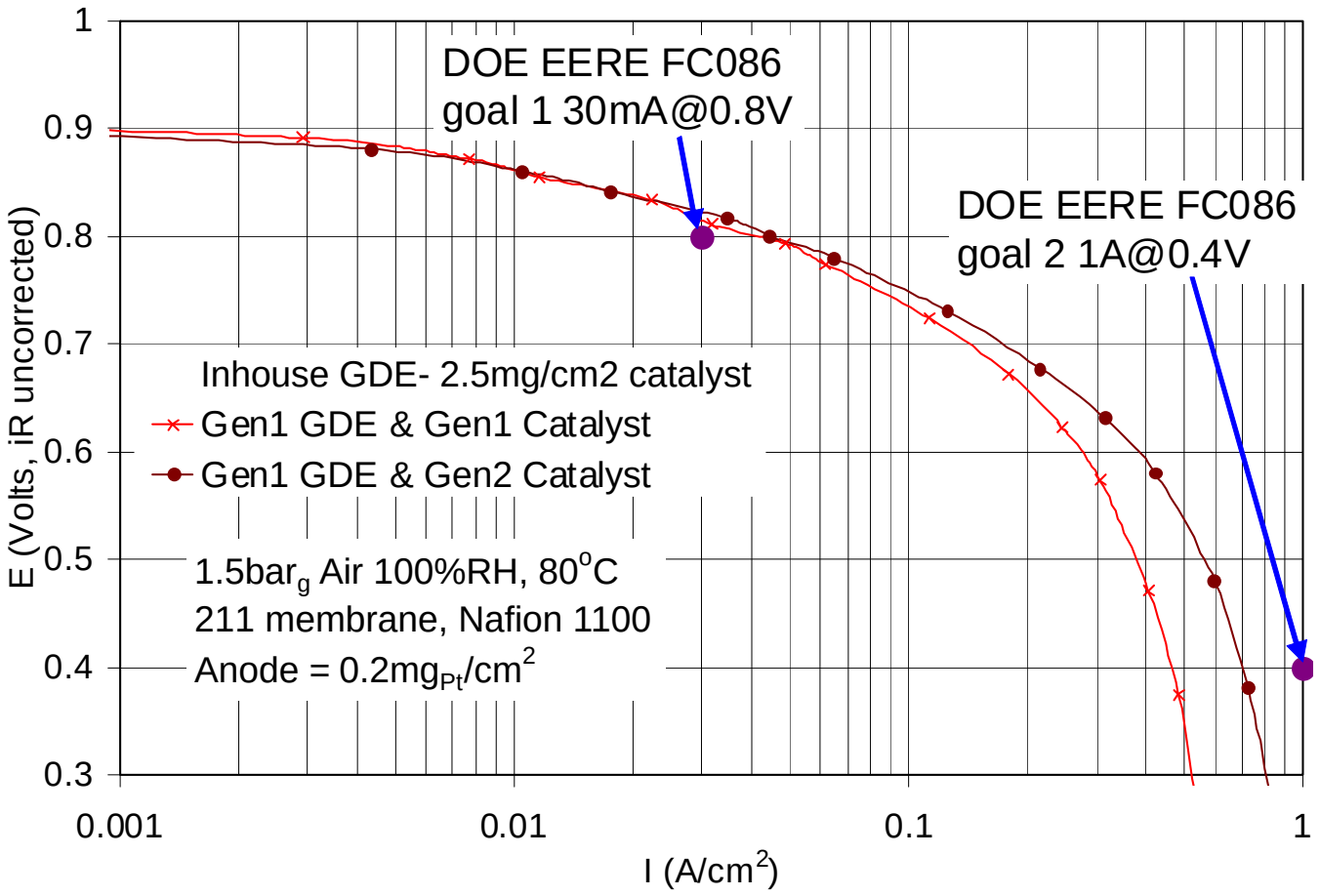
Scaled to 50 g





- Significantly reduced variability (<5%), both inter-batch and intra-batch.
- Consistent performance across different sources of pre-cursor material.

Progress in Air



Improved catalyst formulation meets Goal 1, nearing Goal 2

PPC Capabilities

- Multiple non-PGM catalyst production methods and formulations scaled to 25-100 g
- Fixed product line (200 g/day capacity)
  - ***NPC-2000 & 1000:*** Non-platinum, drop-in fuel cell catalysts with different performance/price points
  - ***PHC-3000:*** Ultra low loaded platinum content catalyst for higher performance
- Custom catalyst design
- Contract manufacturing

Opportunities – 1

PAJARITO POWDER

- Catalysts
  - Continued material improvement
  - Design for manufacturing
    - Reduced material costs at scale
    - Reduced manufacturing costs at scale
- Electrodes
  - Designs for non-PGM catalysts
    - Construction of inks
    - Depositions of inks
    - Construction of MEA

Opportunities – 2

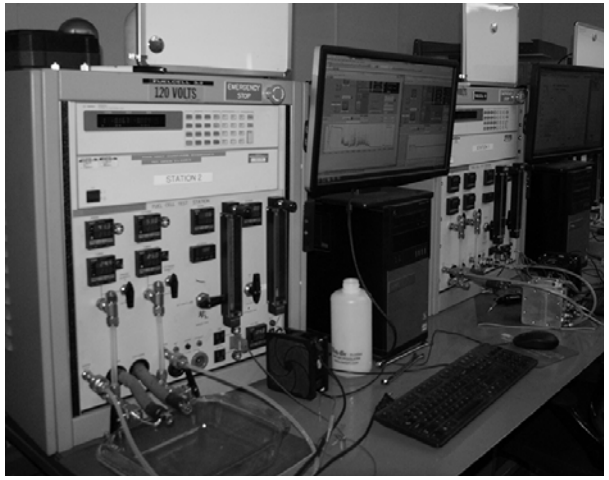
PAJARITO POWDER

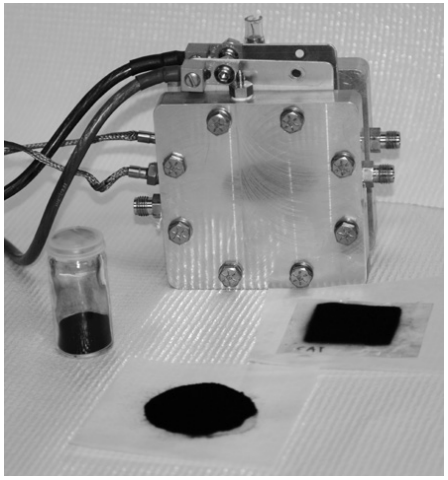
- Standards and Goals
  - Updated/New Protocols for non-PGM
    - Advanced Stress Testing
    - Measurements at End-of-Life (EOL)
  - More representative testing conditions
  - Economic, not just performance standards
- Economics
  - Cost/benefit tradeoffs at the stack & system level
    - For Non-PGM catalysts
    - For ultra-low PGM catalysts

Thanks

- DOE EERE & CWG
  - Northeastern University
    - Prof. Sanjeev Mukerjee
  - University of New Mexico
    - Profs. Plamen Atanassov and Alexey Serov
  - Michigan State University
    - Prof. Scott Calabrese Barton
  - Nissan technical Center North America
    - Drs. Nilesh Dale, Eli Niangar, and Kenzo Oshihara.
  - LANL
    - Drs. Piotr Zelenay, Hoon Chung, and Gang Wu
- Verge Fund

Questions?





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