# Improved Fuel Cell Cathode Catalysts Using Combinatorial Methods

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NuVant Systems Inc.

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This presentation does not contain any proprietary or confidential information

Project ID #
FCP 31

NuVant Systems

# Overview

## Timeline

- **Start date: 7/21/2004**
- **End date:7/13/2006**
- **Percent complete 95%**

## Budget

- **Total project funding**
  - **DOE share:$650,000**
  - **Contractor share:$70,558**
- **Funding received in**

  **FY04:$216,666**

  **FY05-06 : $433,334**

## Barriers

- **Barriers addressed**
  - Uniformity of polarization curves at higher current densities
  - Flow field development for low stoic ratios

## Partners

- T. E. Mallouk, Penn State
- E. S. Smotkin, UPR

# Objectives

**Project objectives**

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**Assist DOE in the discovery of a PEMFC cathode catalyst with an order-of magnitude improvement over state-of-art catalysts to decrease the cathode cost and improve cathode performance.**

- **To establish high throughput discovery methodology**
  - **To address issues concerning uniformity of polarization curves at high current density.**
  - **Evaluate row and column switching strategies**
  - **Upgrade array fuel cell flow field design**

- **Optimize operating conditions for the high throughput synthesis of catalysts on a synthesis/analysis working station**
- **To set metrics and baseline data for the array fuel cells by ranking five commercial catalysts**
- **To optimize synthetic route for the size-controlled synthesis**

# Approach

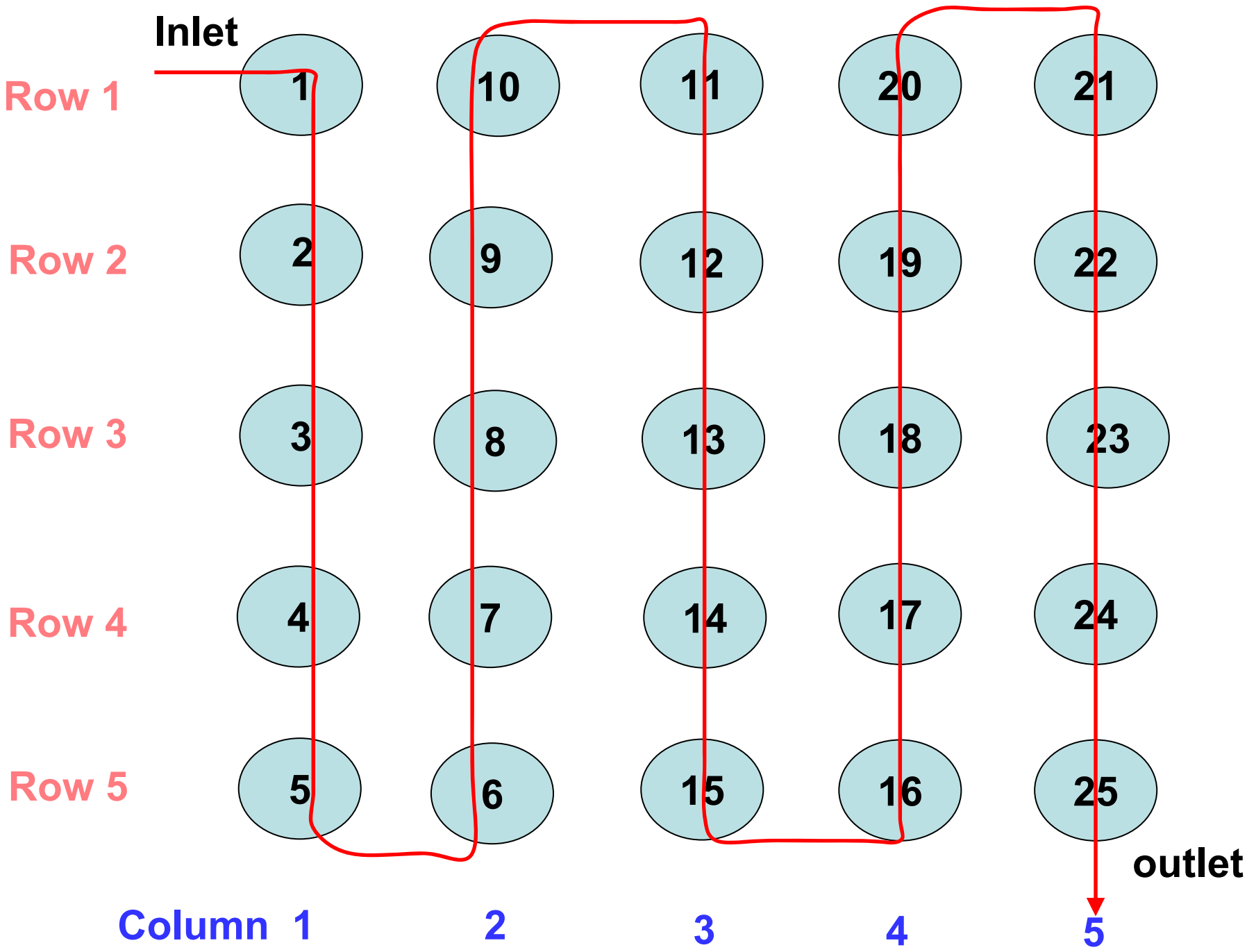
- Development of revolutionary cathode catalysts for the PEMFC through an integrated discovery program
  - Optimize catalyst library configurations on array flow fields
  - Improve robustness of instrument electronics
  - Develop parallel flow fields as an alternative to serpentine flow fields for row switching and low stoic ratios
  - Development of synthetic routes
- Confirm improvements enabled by row and column switching using standard catalyst at cathode array side

# Partial matrix screening cathode catalysts on a serpentine flow field

- Electronics of potentiostat have been modified to switch out rows or columns of array spots
- A variety of sample maps are used to evaluate switching applications
- Complete measurement at all 25 spots and data analyses
- Partial matrix measurements (Column switching, Row switching and Latin Switching)
- Data analyses for partial matrix measurements

# A 5X5 array MEA with 7 GDL disks removed

# 1. Sample maps



# 2. Complete measurements

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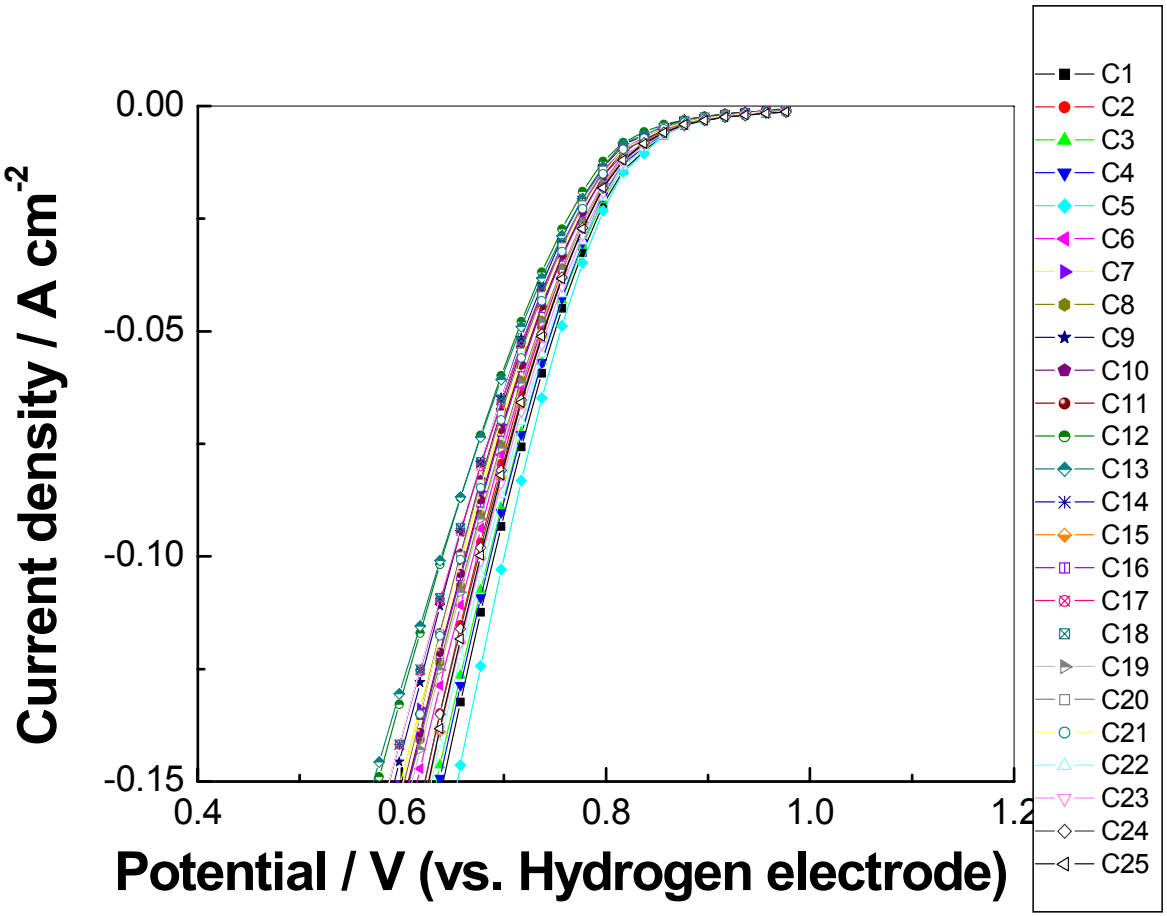
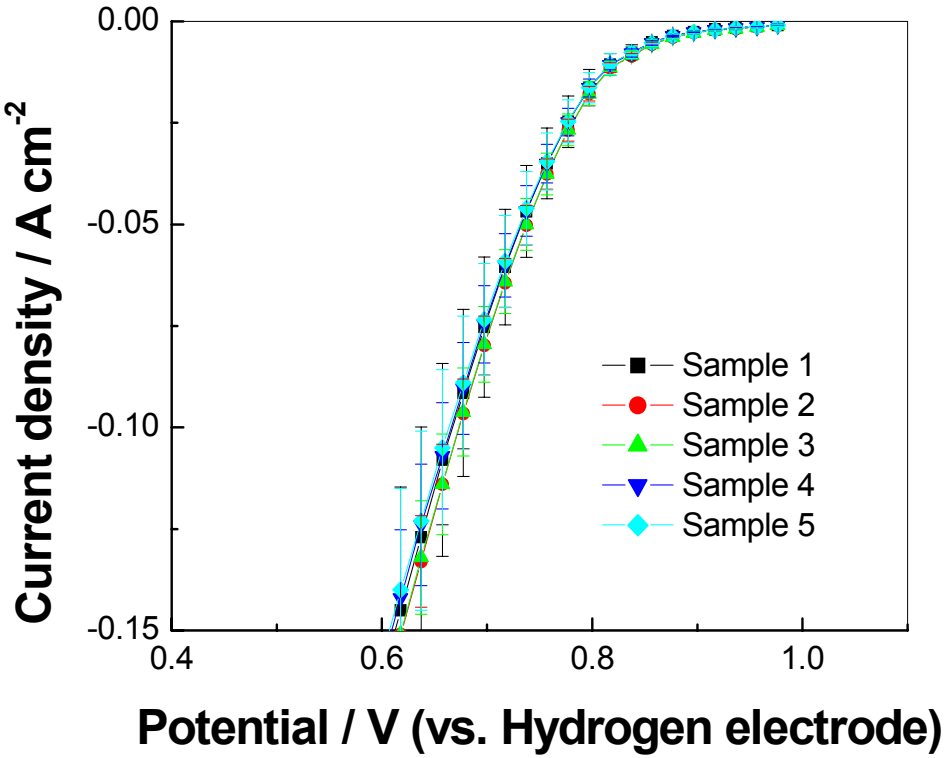
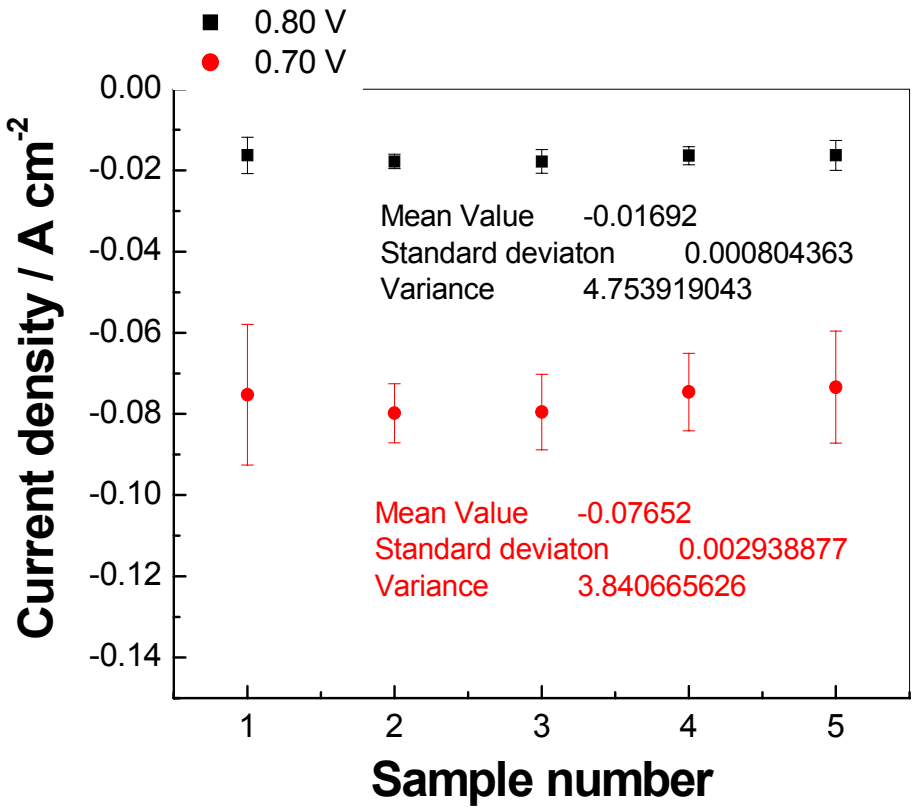
## (a) Overall polarization curves at all 25 spots in kinetic zone. Note excessive spread at higher current densities.



# (b) Data analyses

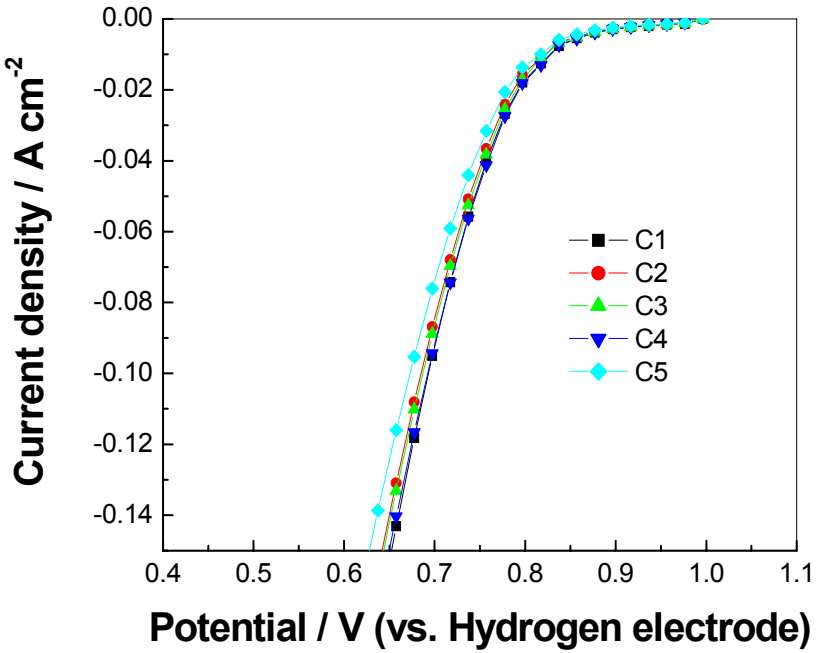
**Left: Mean value curves in a Latin square**
**Right: Mean values at 0.80 and 0.70 V for each sample**



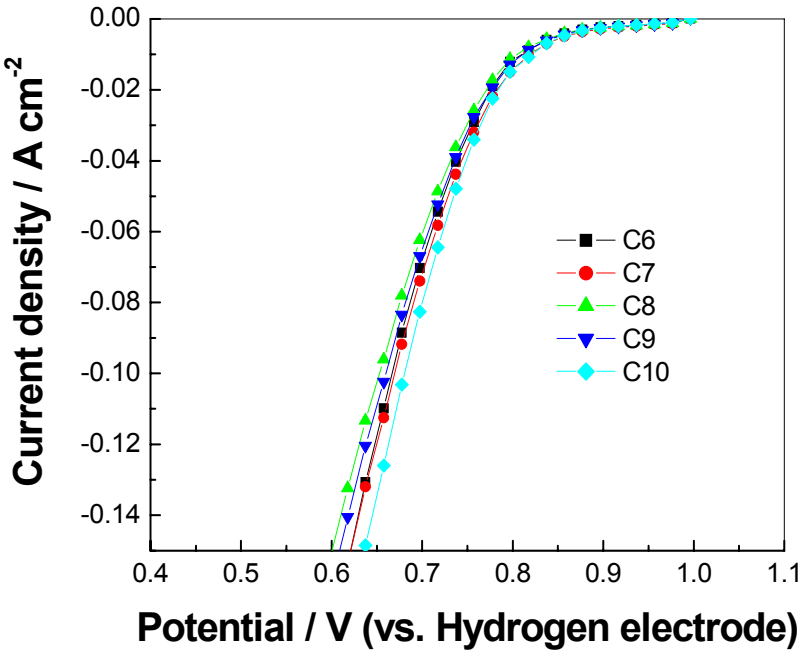



# 3. Partial screening experiments

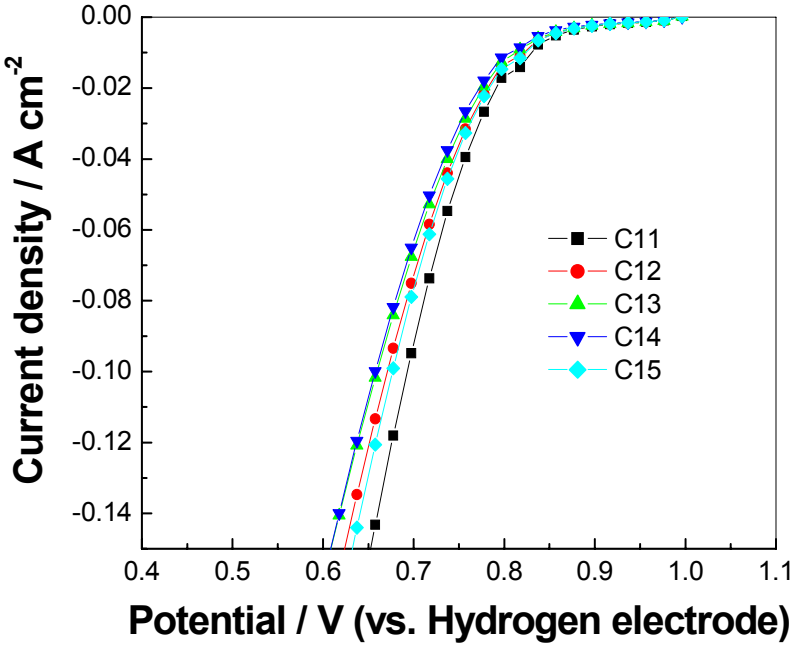
## (a) Column switching (raw data for each column)



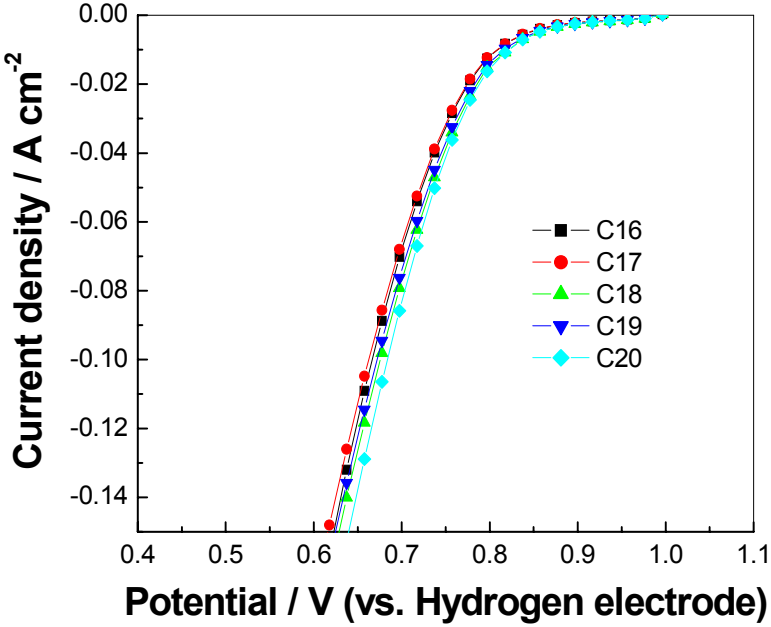

Column 1



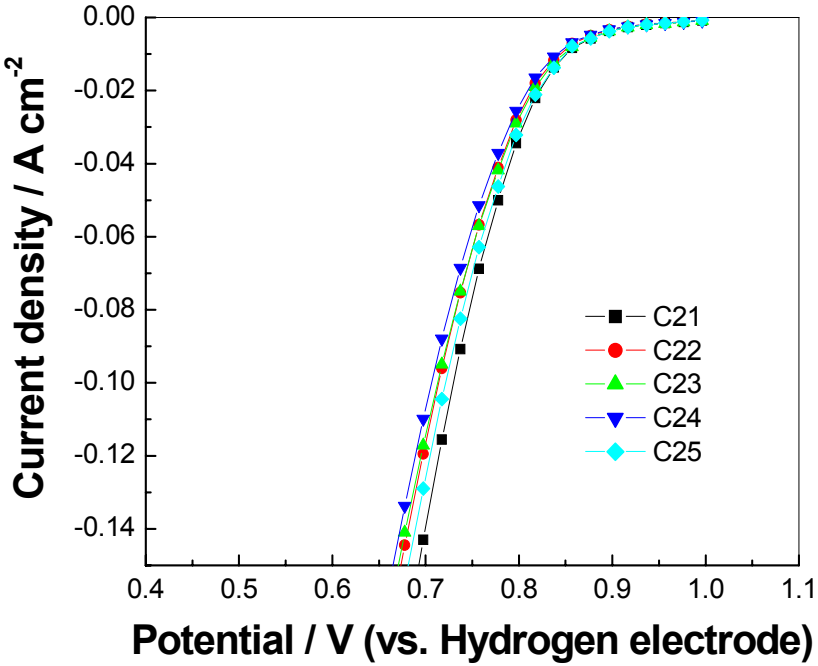

Column 2




Column 3

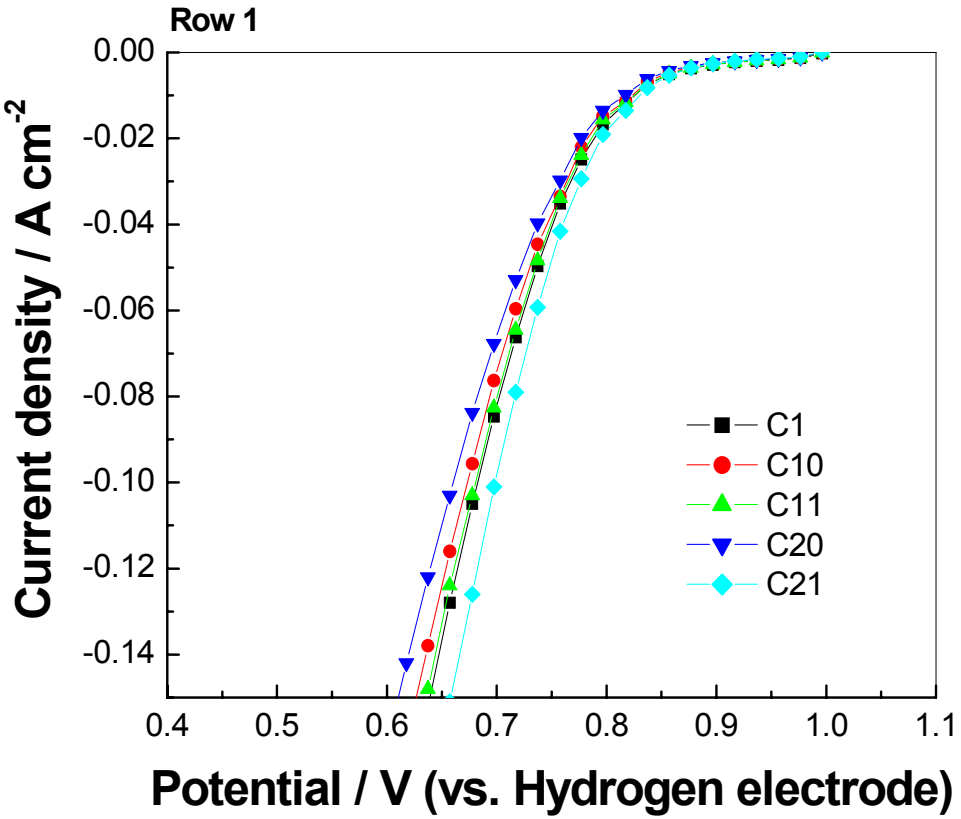



Column 4

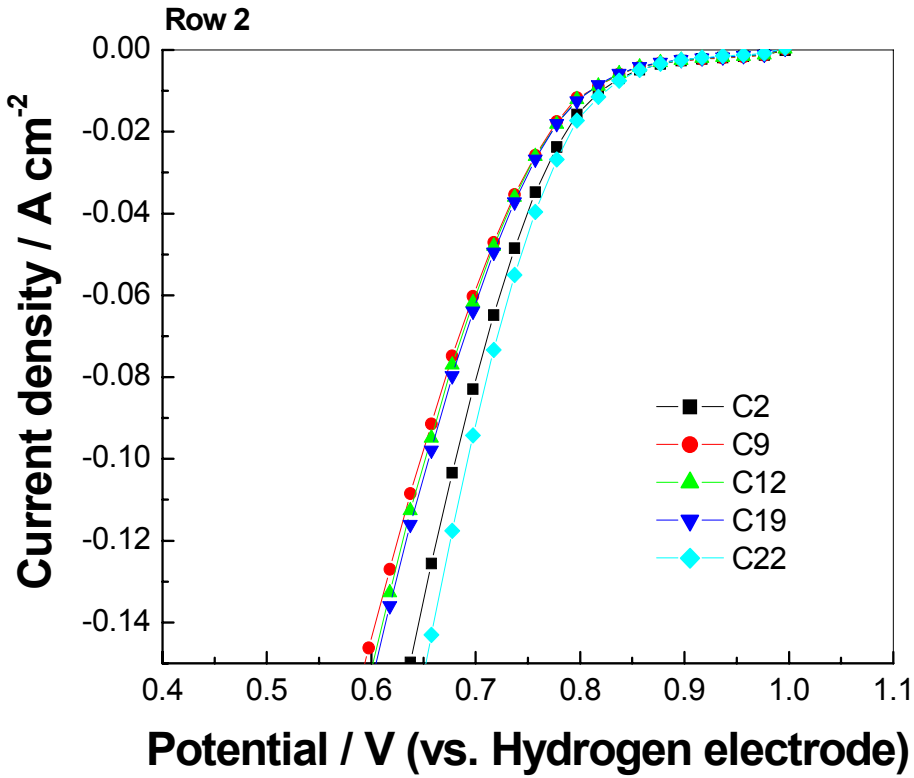



Column 5

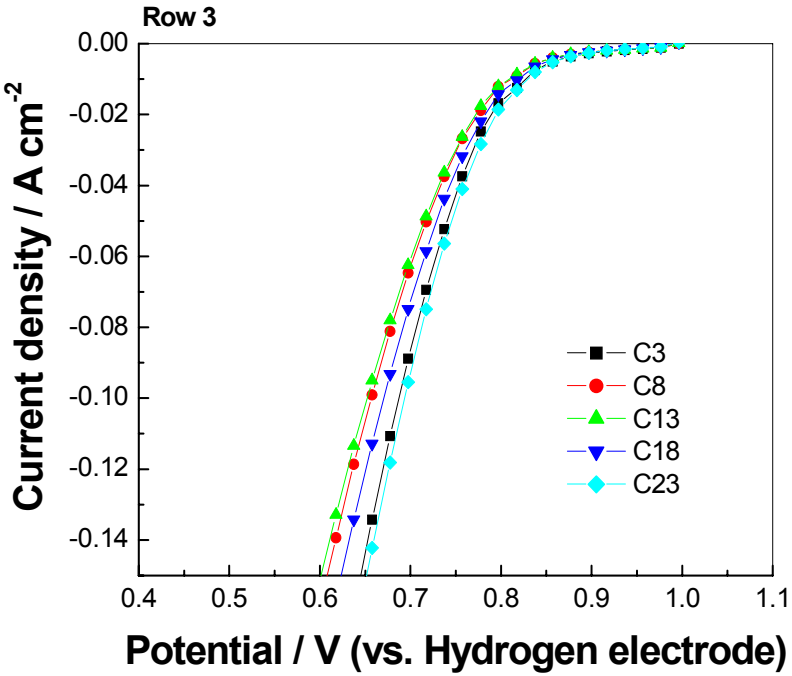
# (b) Row switching (row data for each row)



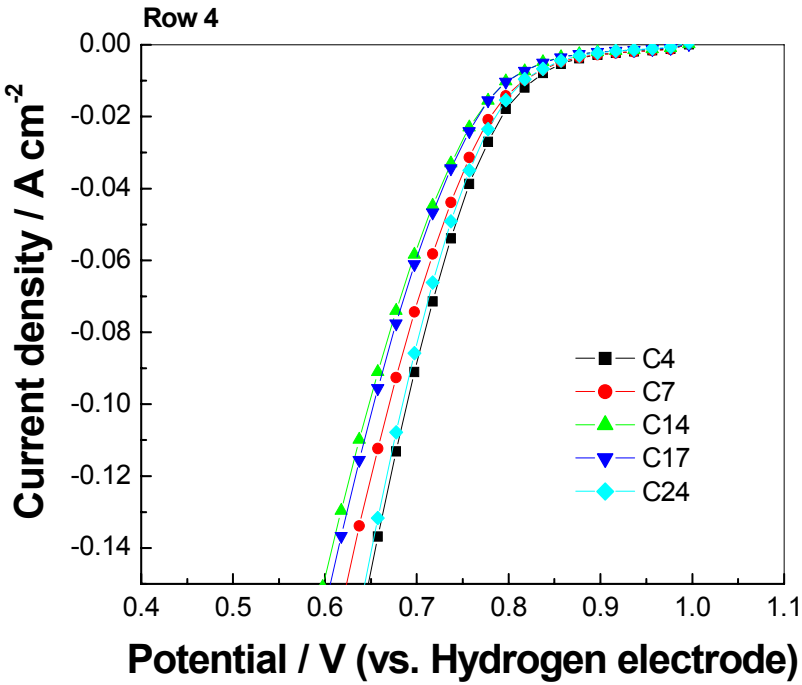

Row 1



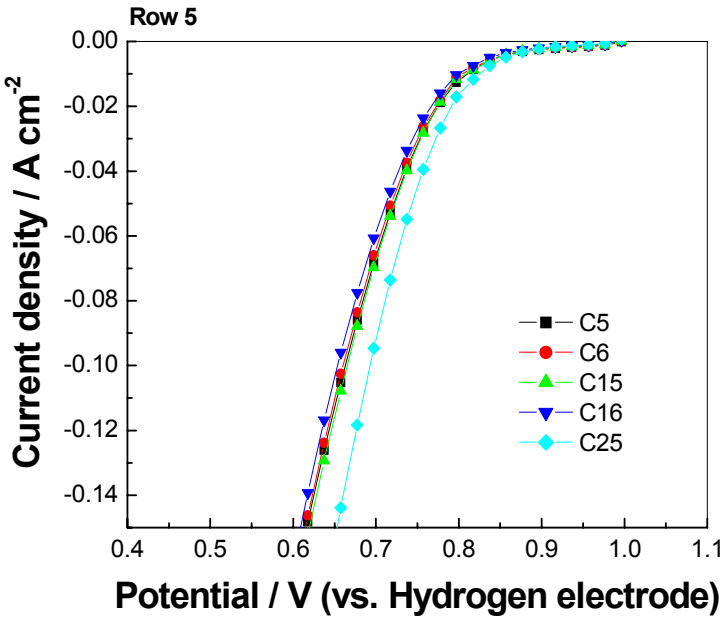

Row 2




Row 3

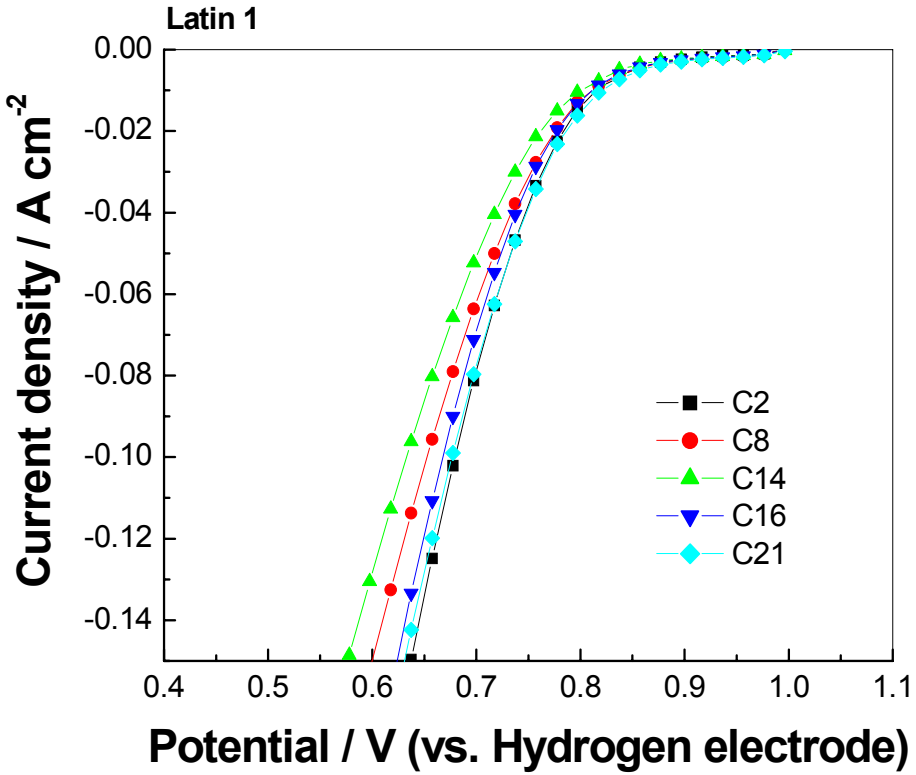


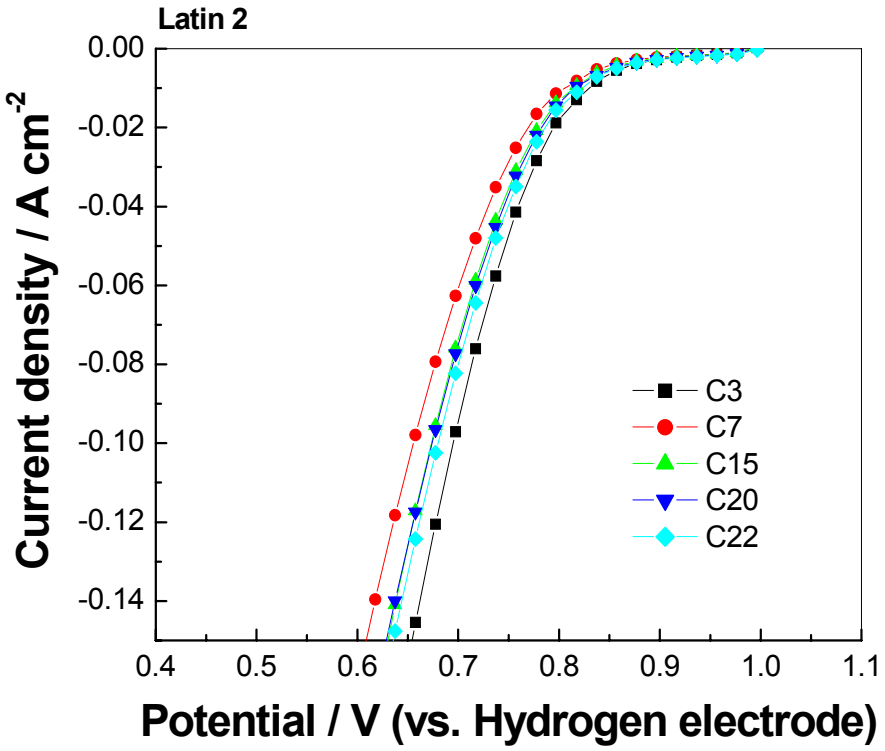

Row 4




Row 5

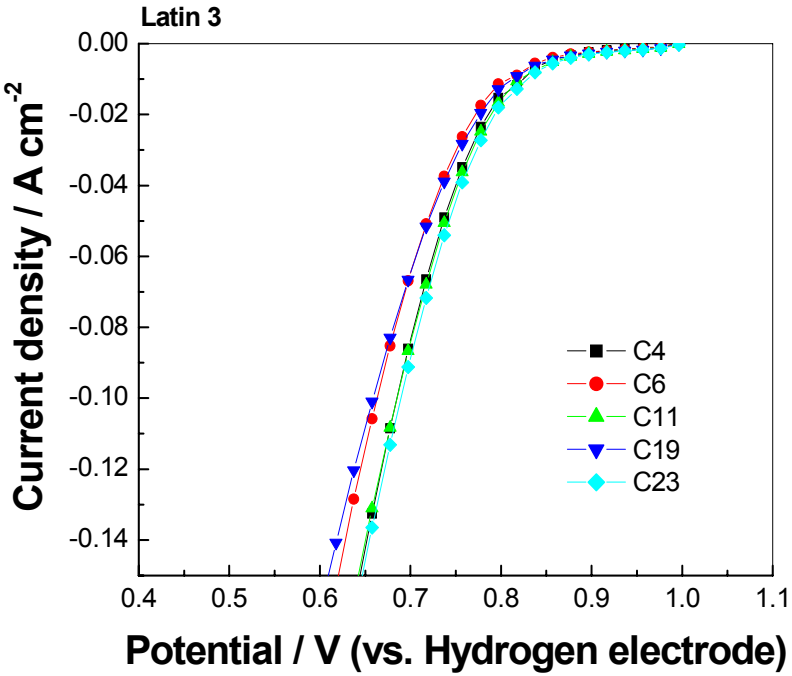
# (c) Latin switching (raw data for each sample number in a Latin Square)



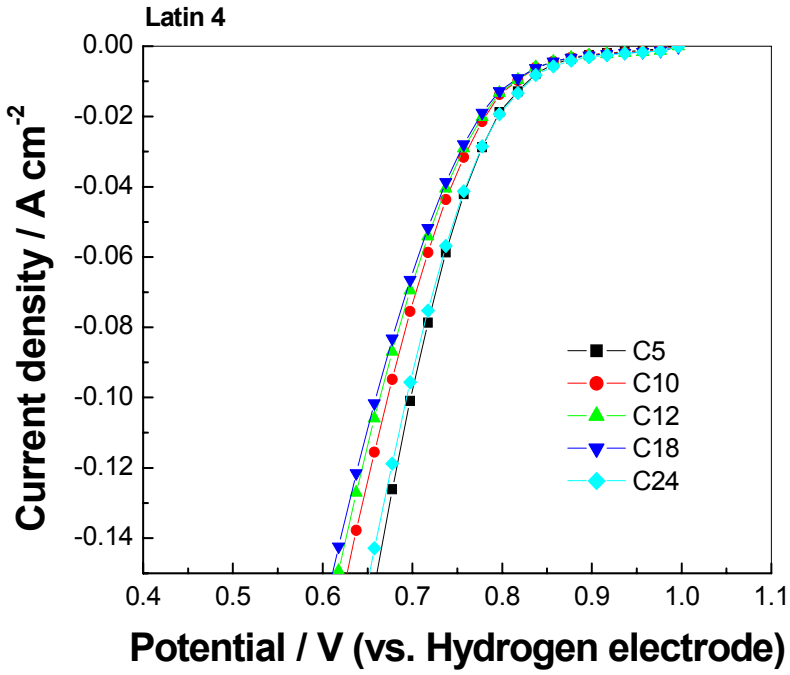




**1 in Latin Square**

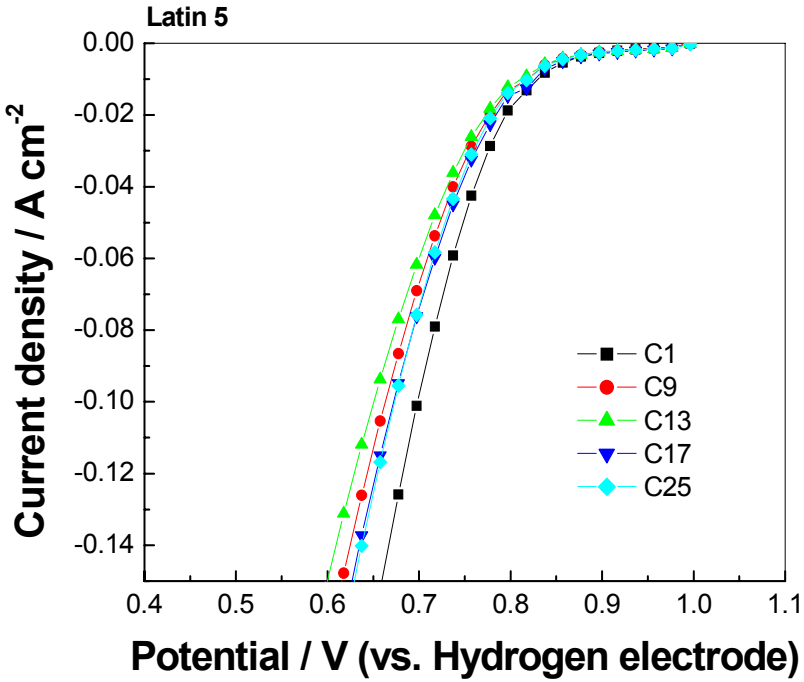
**2 in Latin Square**




3 in Latin Square




4 in Latin Square

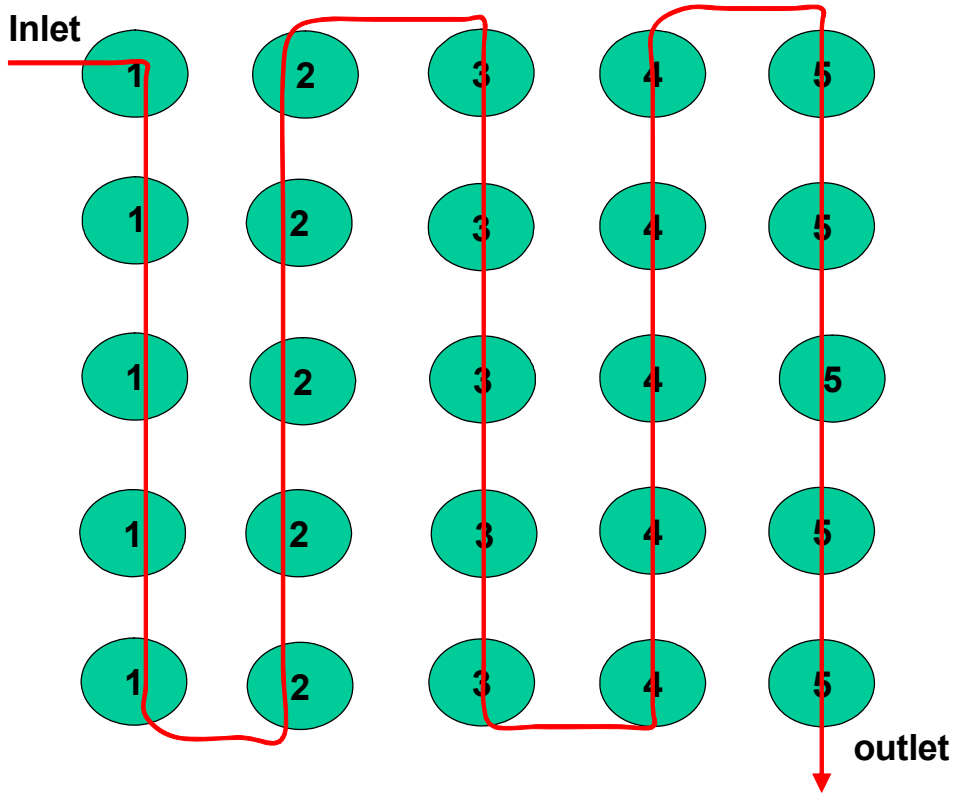


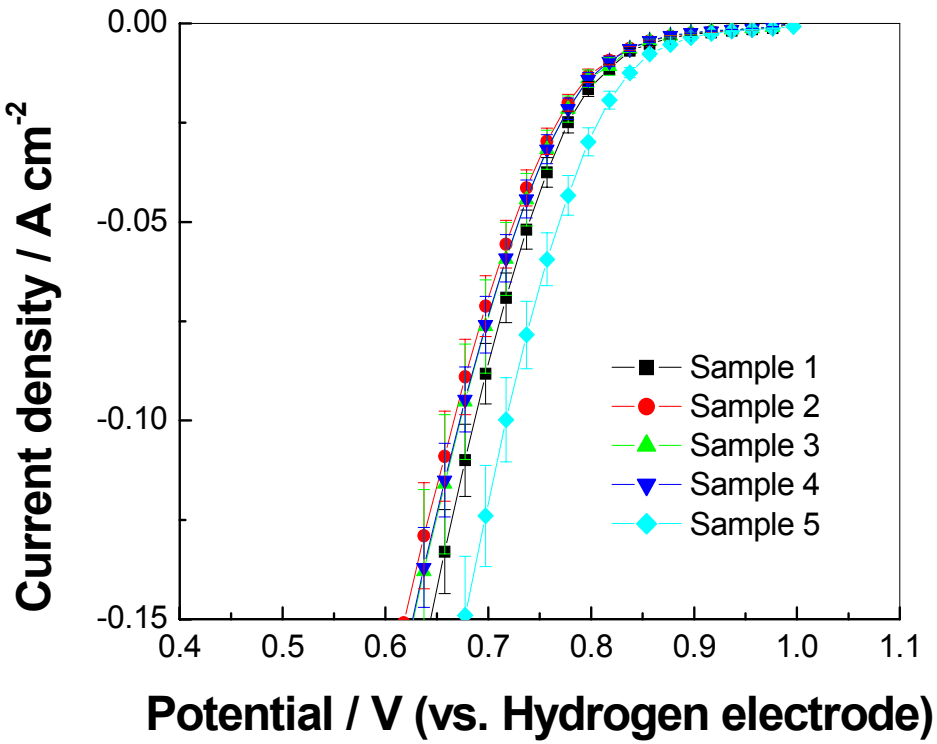

5 in Latin Square

# 4. Data analyses for partial matrix measurements

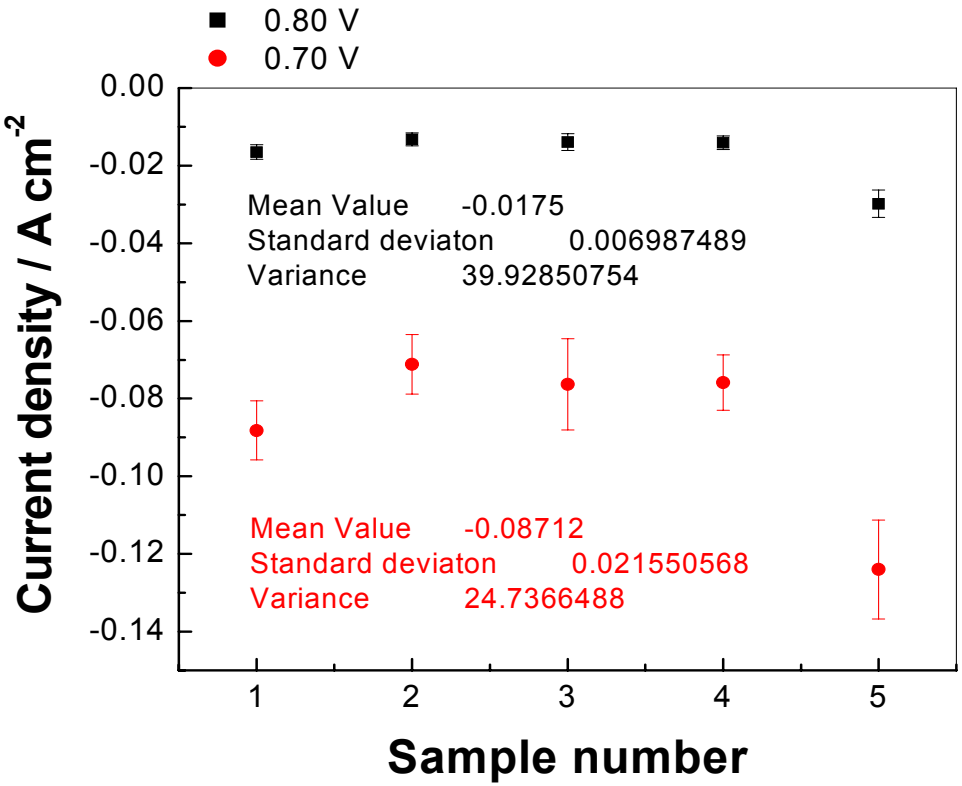
## (a) Column switching

***Strategy 1: One sample lot per column***





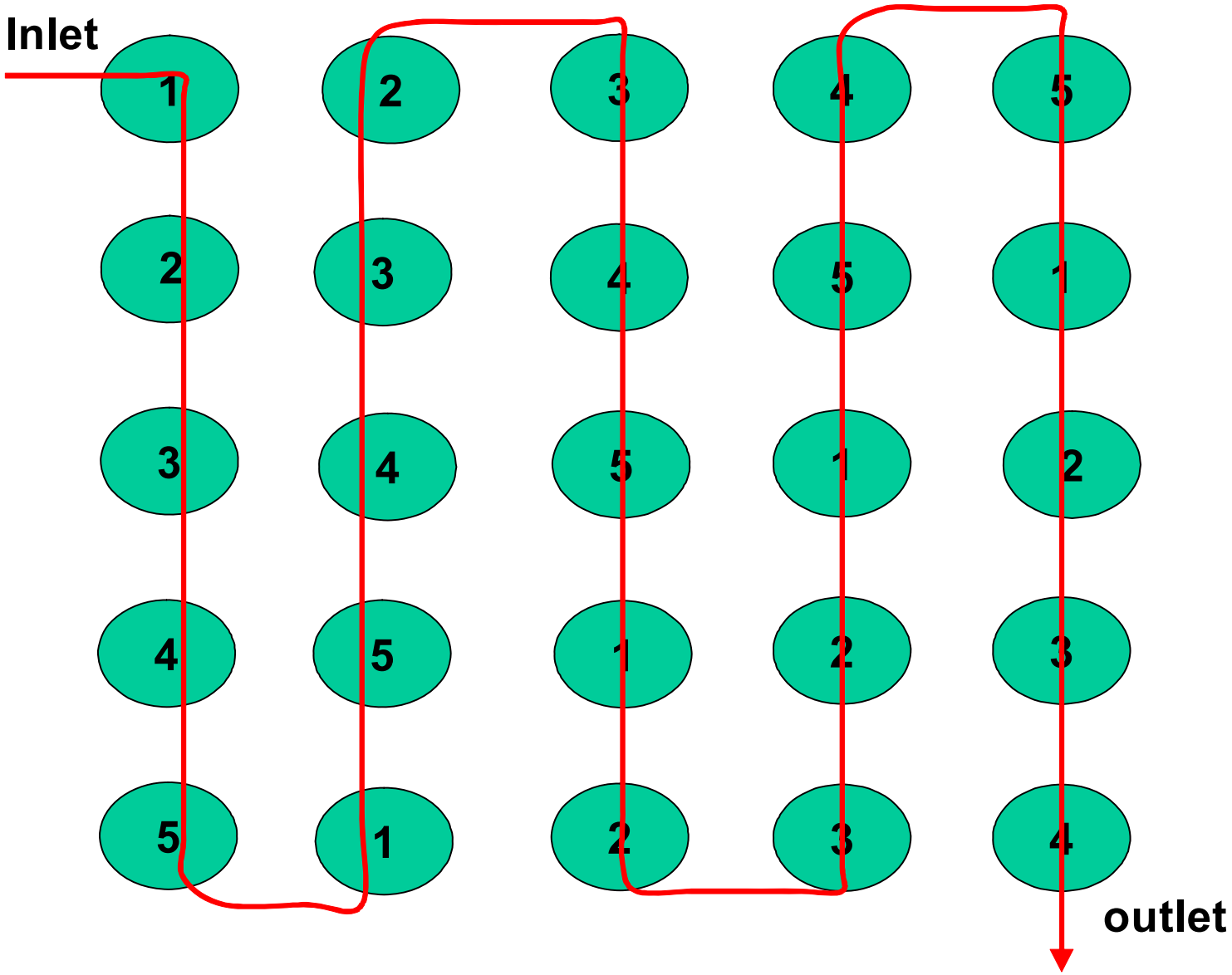

Mean value curves

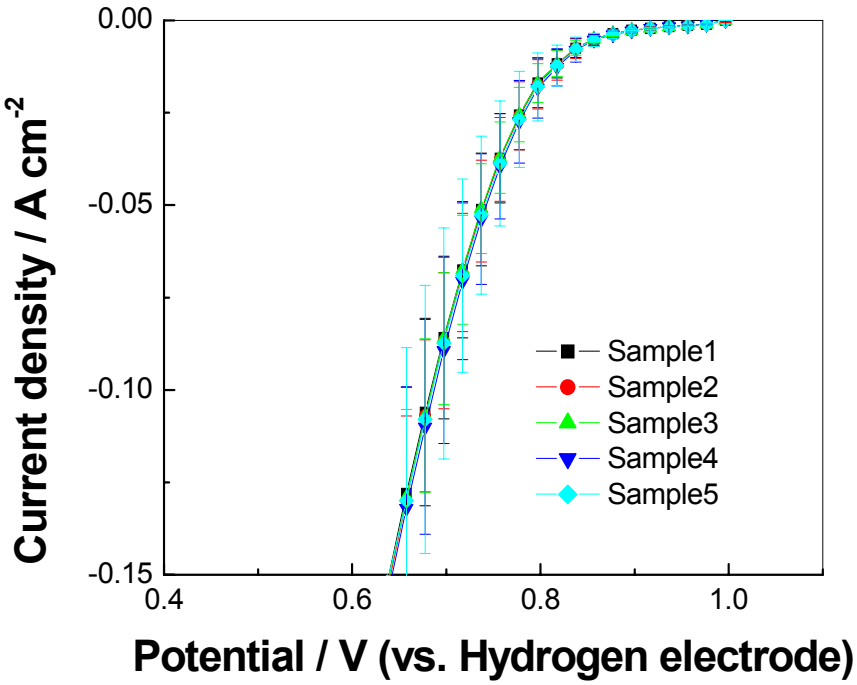



Mean values at 0.80 and 0.70 V for each sample

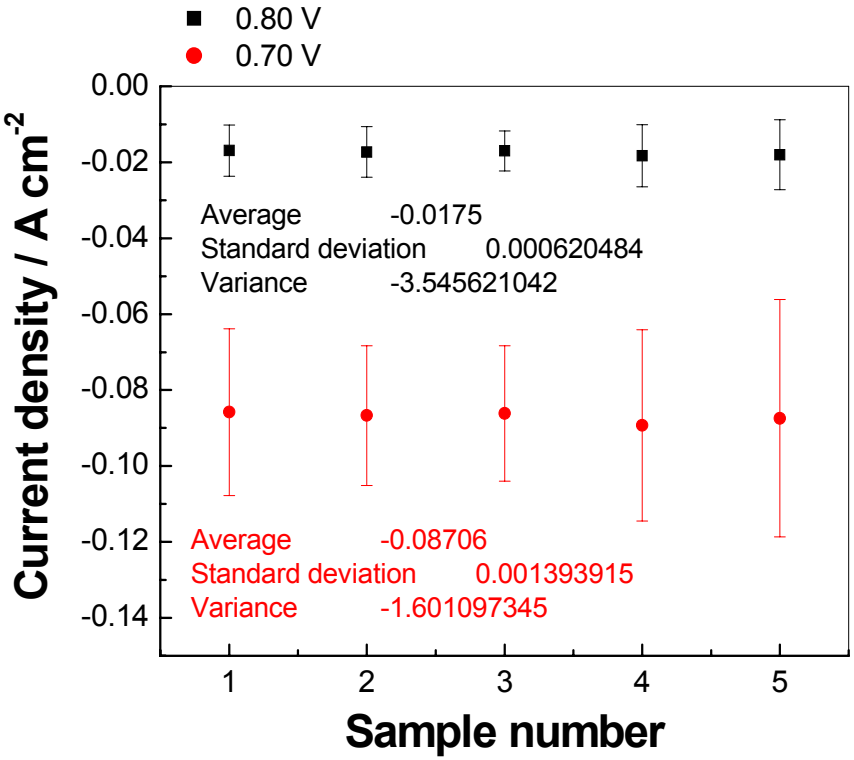
## Comments: Strategy 1 – excessive spread

*(Column switching)* ***Strategy 2: Arrange the samples in a Latin square***






Mean value curves

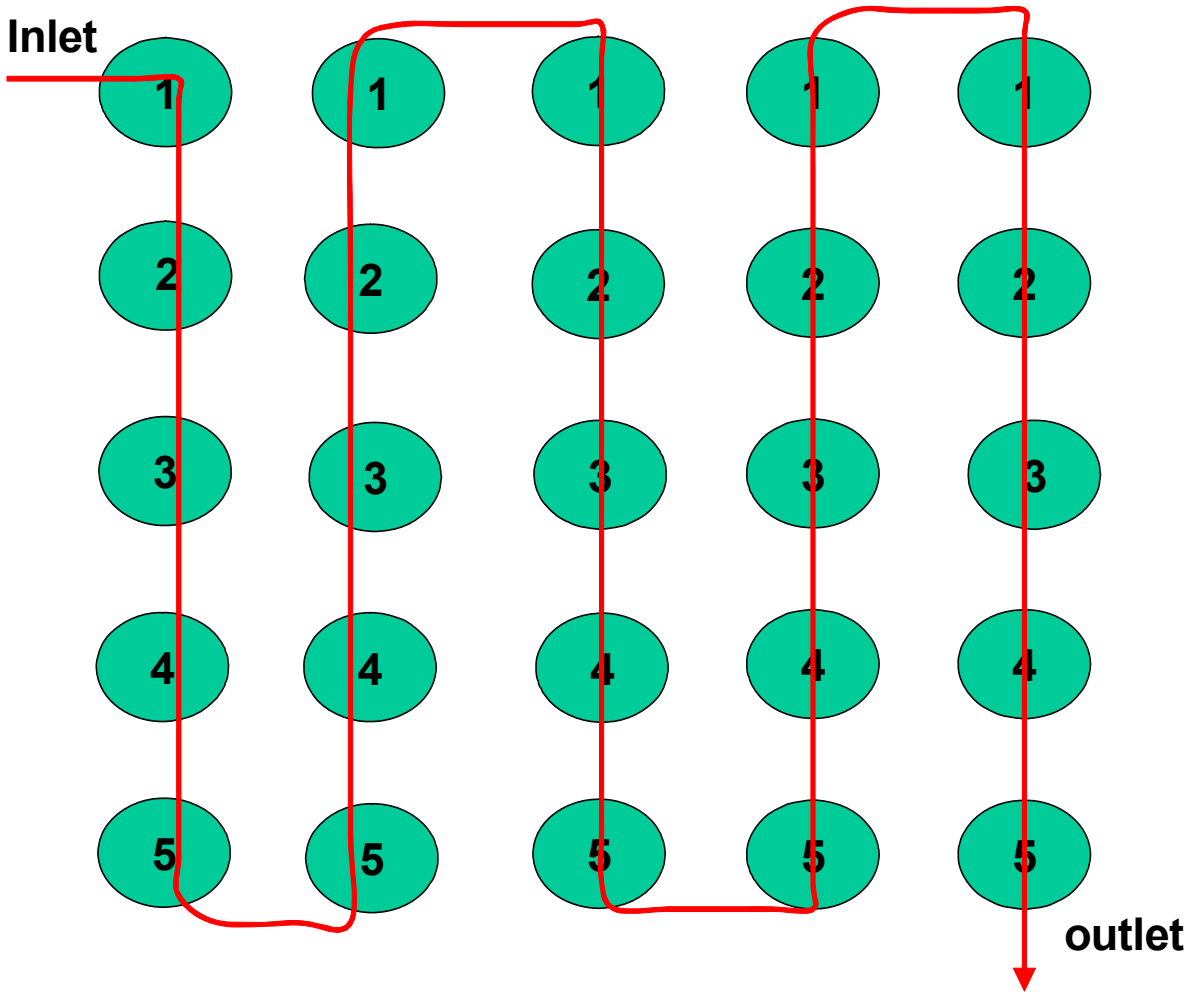


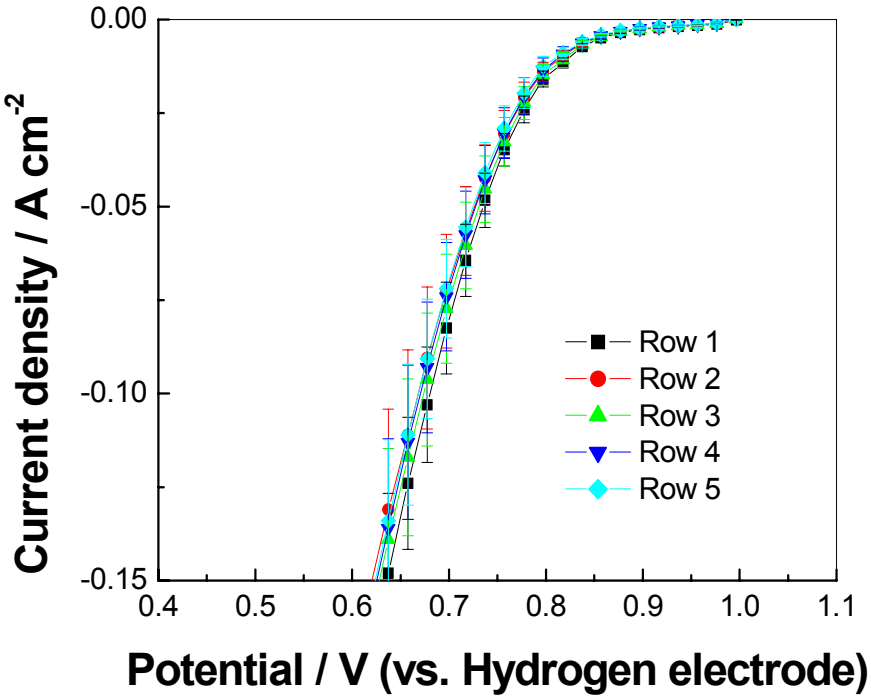

Mean values at 0.80 and 0.70 V for each sample

**Comments: Strategy 2 – substantial reduction of spread**

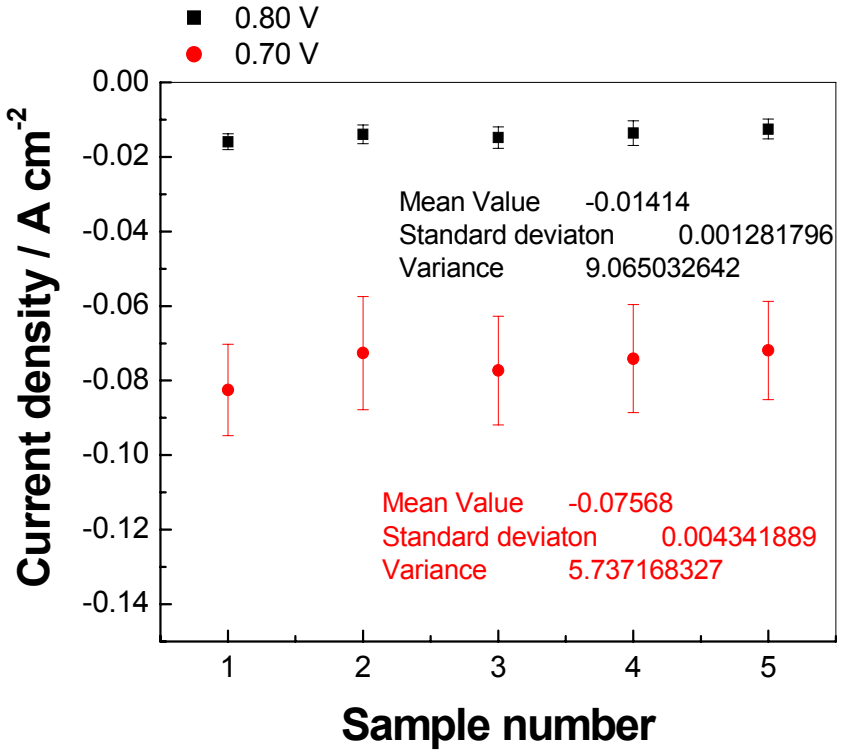
# (b) Row switching

***Strategy 3: One sample lot per row***





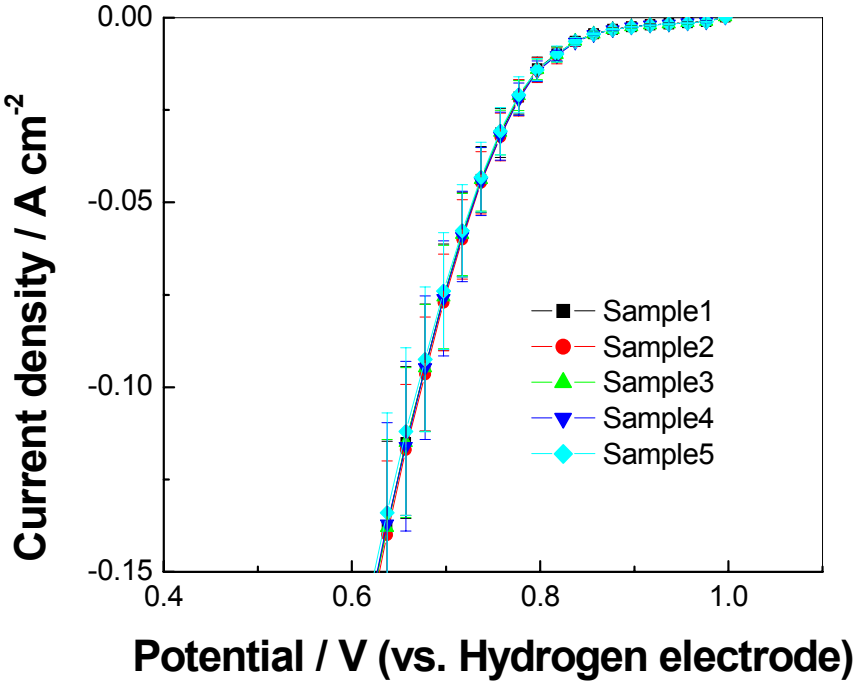

Mean value curves



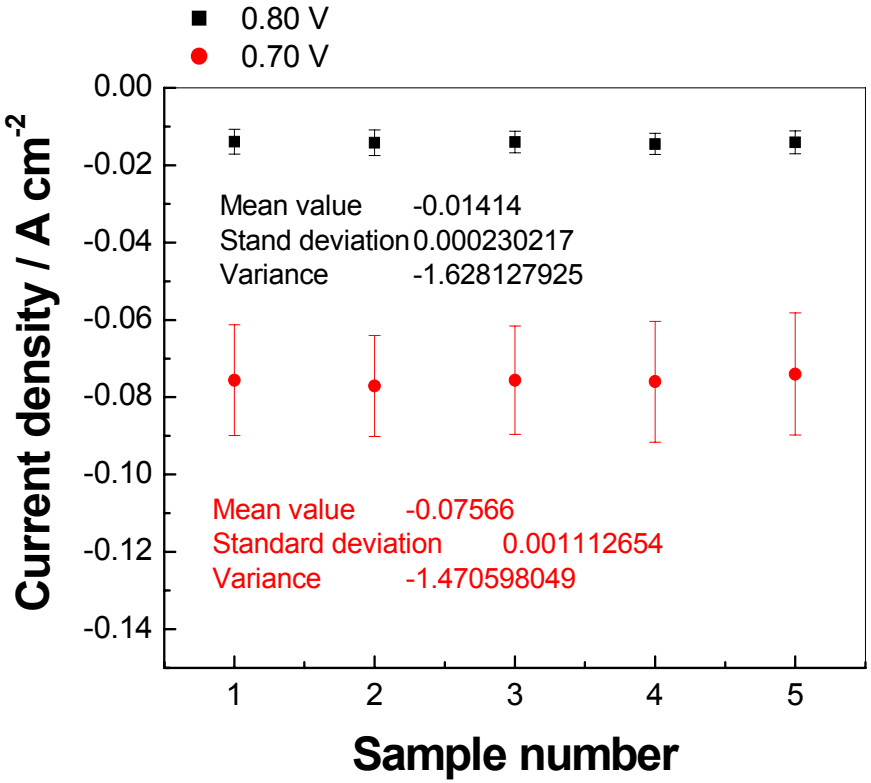

Mean values at 0.80 and 0.70 V for each sample

## Comments: Strategy 3 – excessive spread

# *(Row Switching)* ***Strategy 4: Arrange samples in a Latin square (same as the map on Slide 13)***




Mean value curves

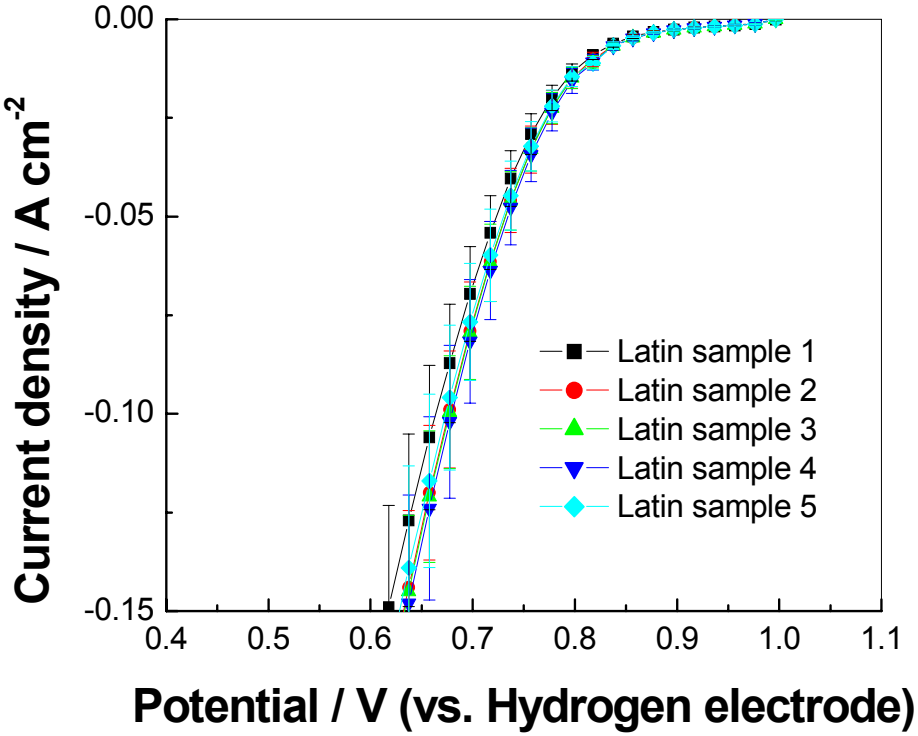



Mean values at 0.80 and 0.70 V for each sample

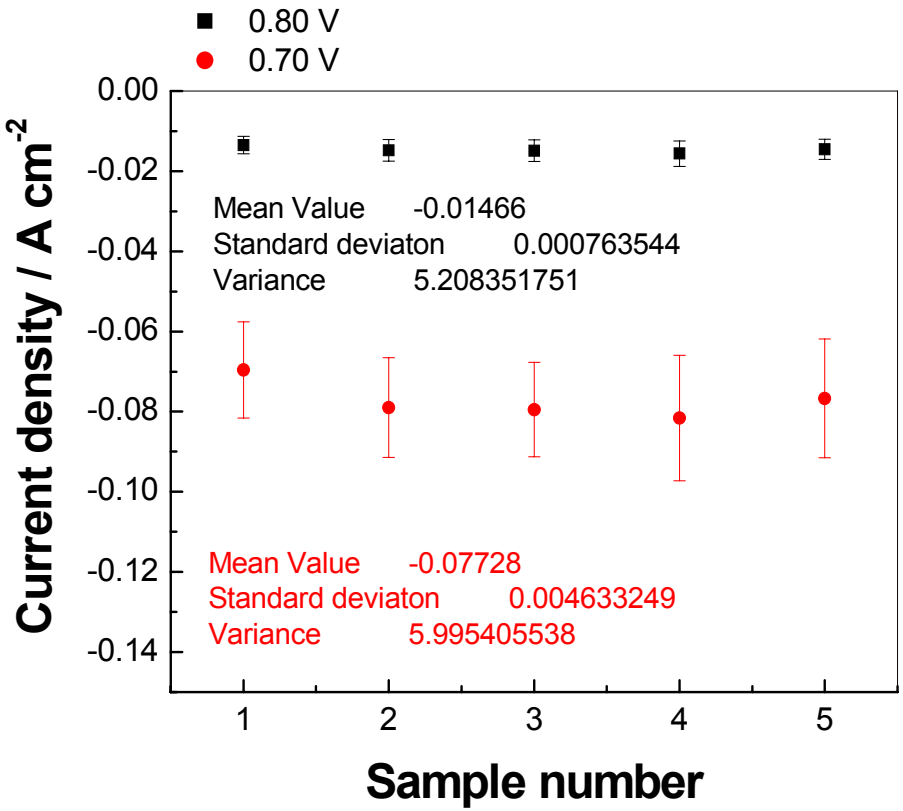
**Comments: Strategy 4 – improved uniformity of sample means**

# (b) Latin switching

***Strategy 5: Latin row switching and data analysis***




Mean value curves




Mean values at 0.80 and 0.70 V for each sample

**Comments: Strategy 5 – poor uniformity of sample spreads**

# Conclusions

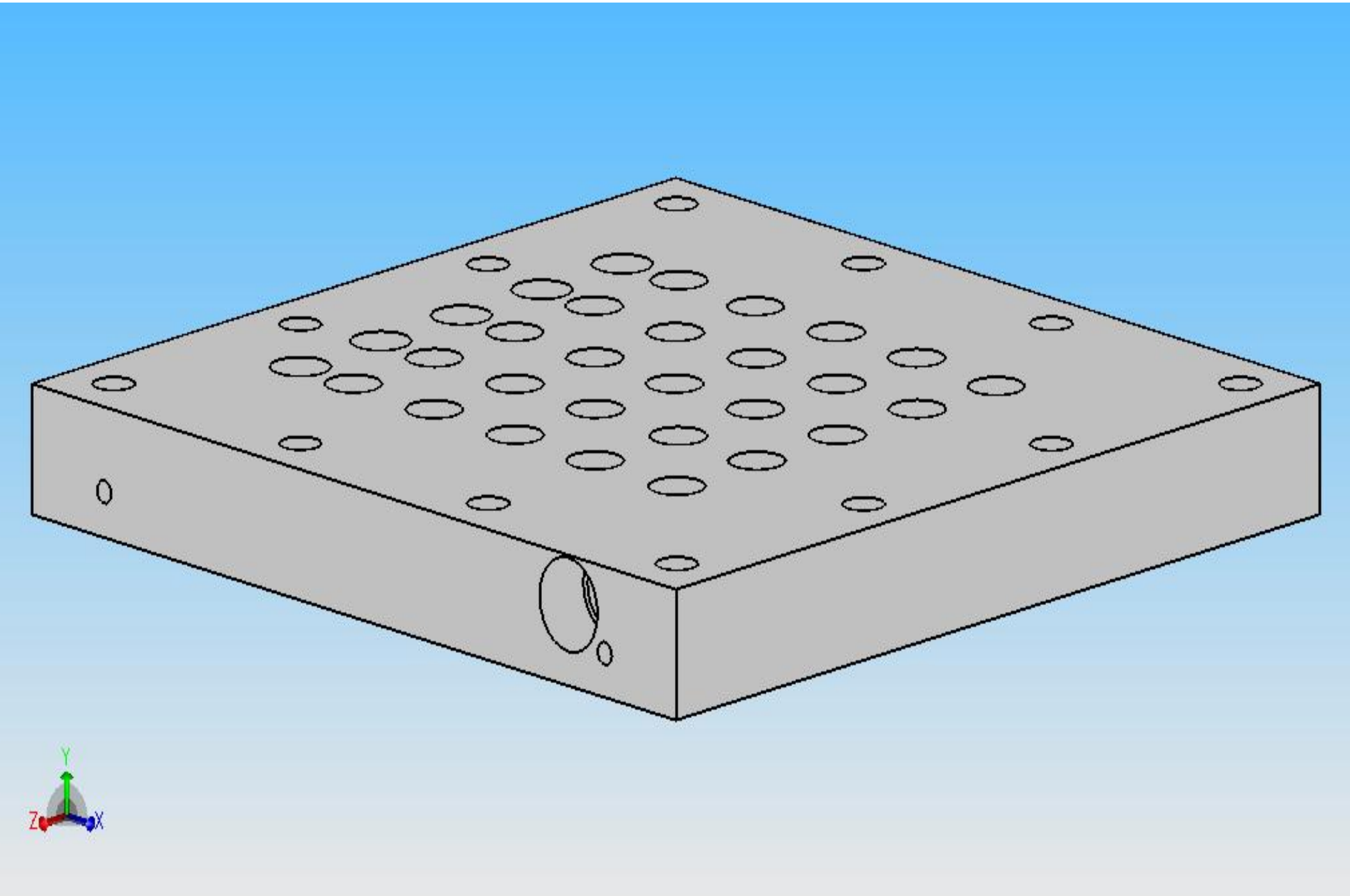
- Partial matrix screening (i.e. row and column switching) shows advantages over full matrix screening in terms of suppressing the spread of mean values for samples grouped in a Latin square.

- Row and column switching enhances Latin square analysis.

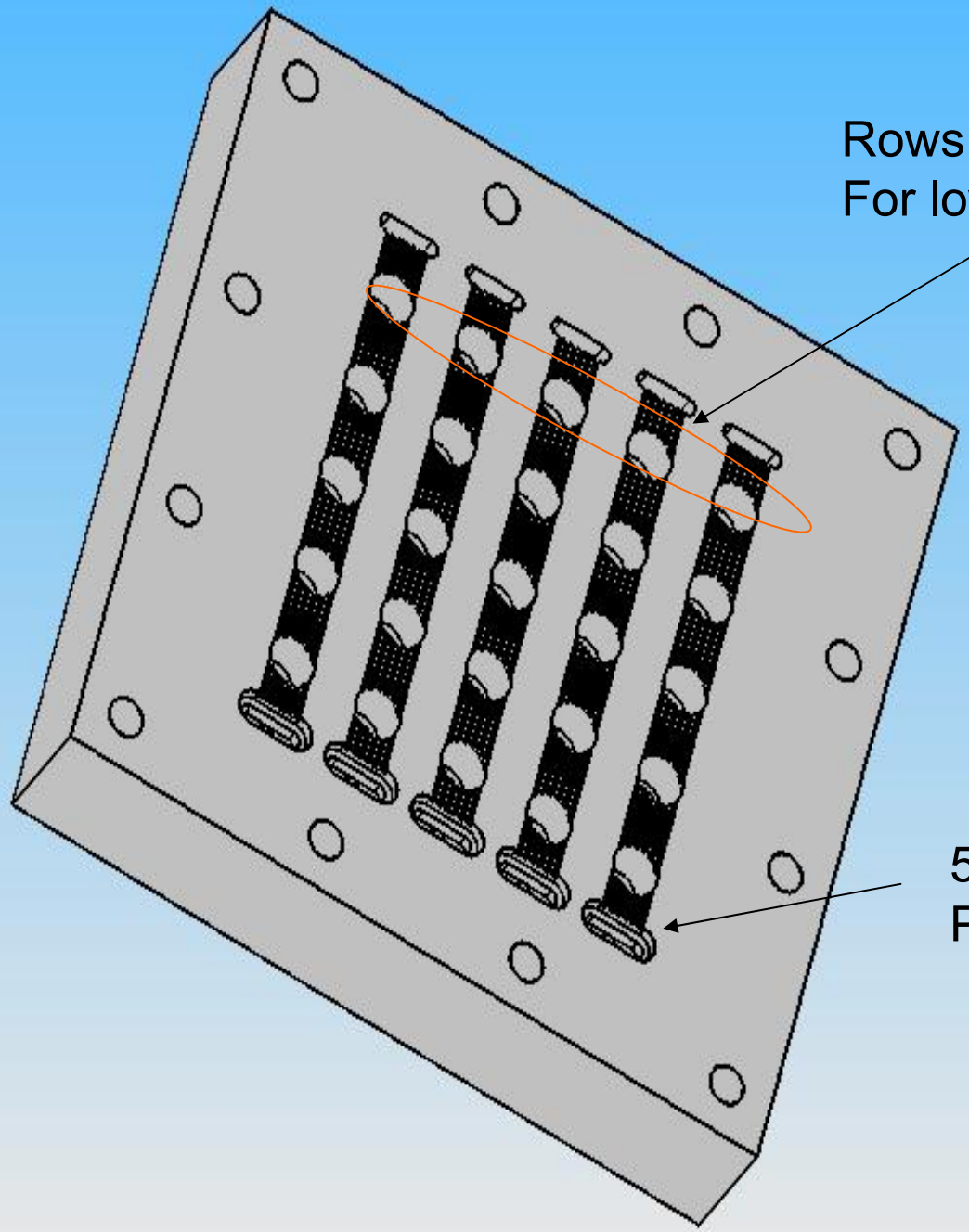
# A new array flow field design is motivated by previous results

- Row and column switching is optimized by utilization of 5 independent flow fields with uniform flow.
- Aluminum endplate design is unchanged
- Parallel array flow field have been developed to optimize switching for low stoic ratios.
- Assembly of array fuel cell and array MEA remains unchanged.
- Delivery of parallel cell to Cabot expected in early July of 2006.

# Aluminum endplate with feed-through ports for array electronics



# Parallel array flow field for optimized row and column switching at low stoic ratios.



Rows individually selected
For low stoic applications

5 Inlets through
Pressure dropping frits

# Assembled parallel array fuel cell

(Actual cell will be on display during poster session.)

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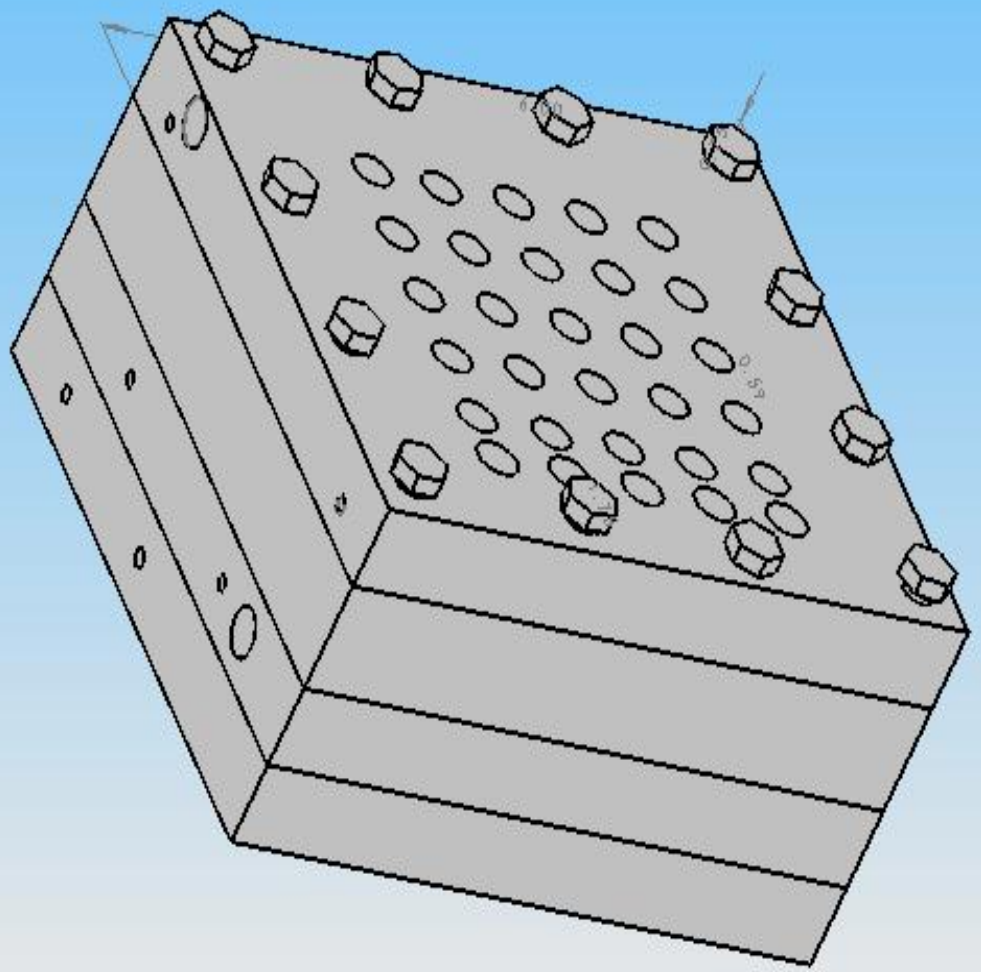

# Future Work

- Remainder of FY 2006 (Cost share period)
  - Continuous combinatorial screening of catalysts
  - Size-controlled synthesis of five promising candidates. Catalysts have already been prepared by Penn State and will be screened with new flow field and electronics.
  - Demonstration of the five candidates with optimized size in a single cell
  - Develop and utilize heuristic rules for the development of next generation PEMFC cathode catalysts

# Publications and Presentations

E. S. Smotkin, J. Jiang, A. Nayar, S. Chung, R. Liu, *High-throughput screening of fuel cell electrocatalysts*, **Applied Surface Science**, Volume 252, 7, pp 2573-2579, **(2006**)

B. C. Chan, R. Liu, K. Jambunathan, H. Zhang, G, Chen, T. E. Mallouk, and E. S. Smotkin, "*Comparison of High Throughput Electrochemical Methods for Testing Direct Methanol Fuel Cell Anode Electrocatalysts*," **J. Electrochem Soc**, **152,** A594-A600 (**2005**)

Row Switching System for Array Fuel Cell Reactors, E.S. Smotkin U.S. Patent Application Serial No. 11/061,483

# Hydrogen Safety

The most significant hydrogen hazard associated with this project is:

Possible fire hazard with fuel side.

# Hydrogen Safety

## Our approach to deal with this hazard is:

We place hydrogen cylinder and oxygen cylinders 10 ft apart and have flash arrestors at the inlets of the fuel cell. Outlet gases are vented to a fume hood that vents to the outside of the lab.