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

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

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

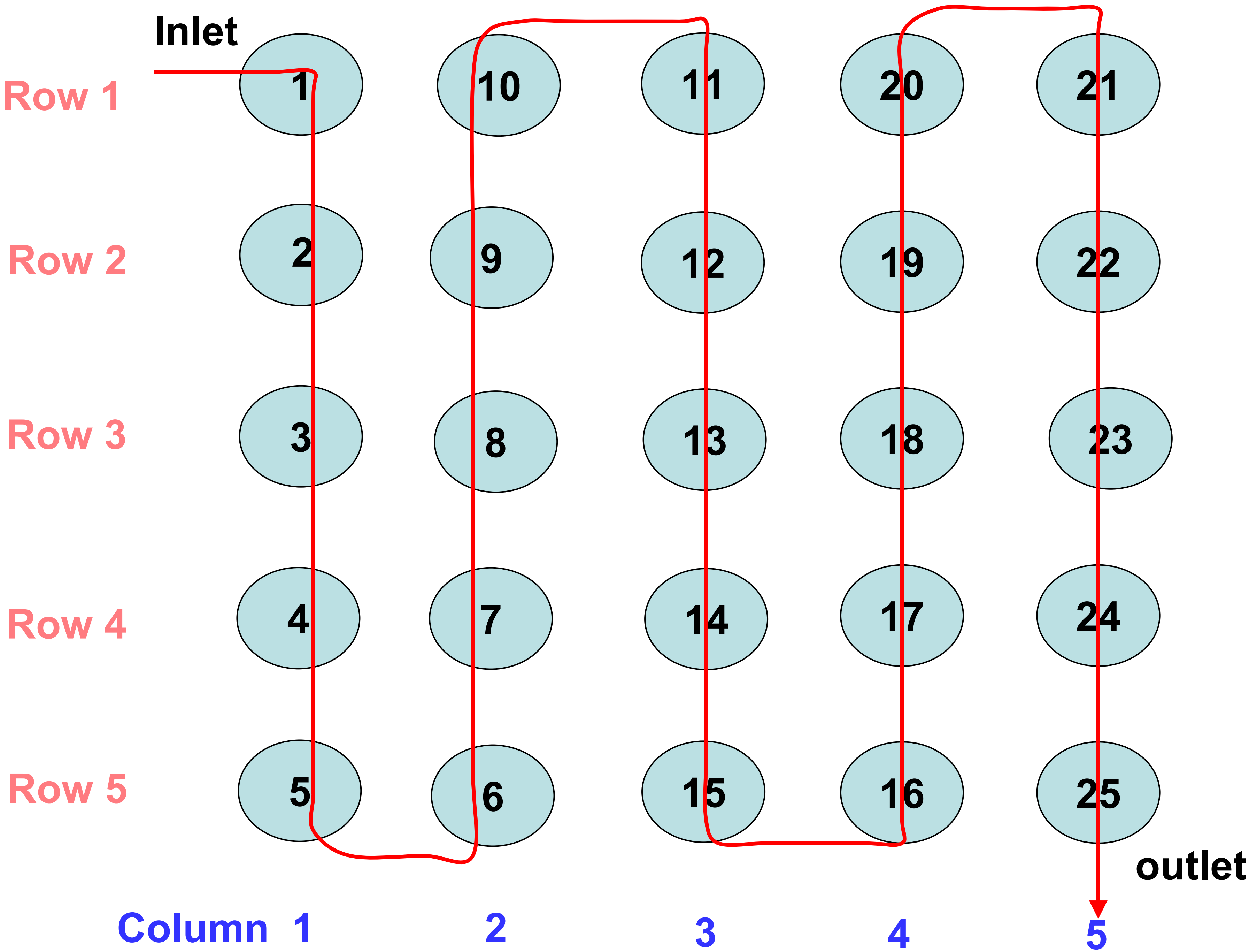
- Complete measurement at all 25 spots and data analyses

- Partial matrix measurements (Column switching, Row switching and Latin Switching)

- Data analyses for partial matrix measurements

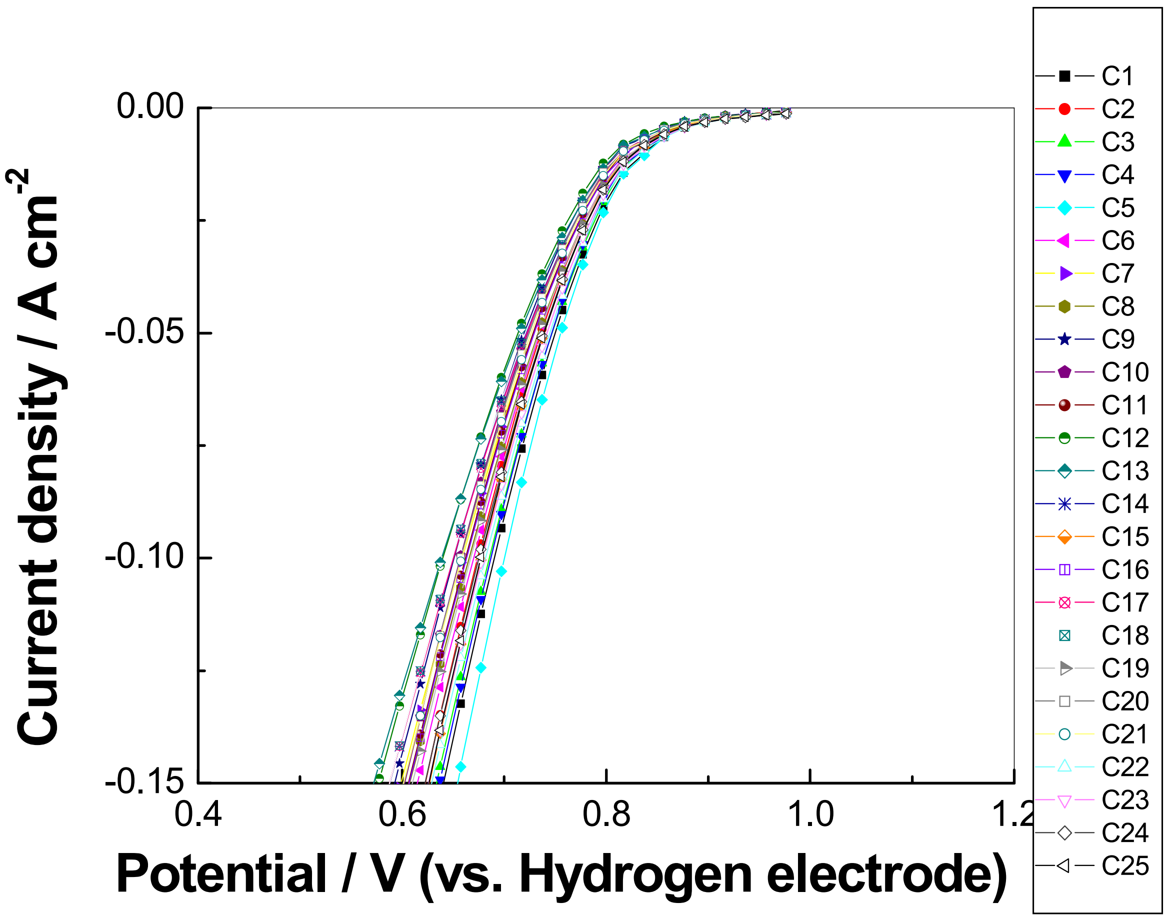
A 5X5 array MEA with 7 GDL disks removed

1. Sample maps



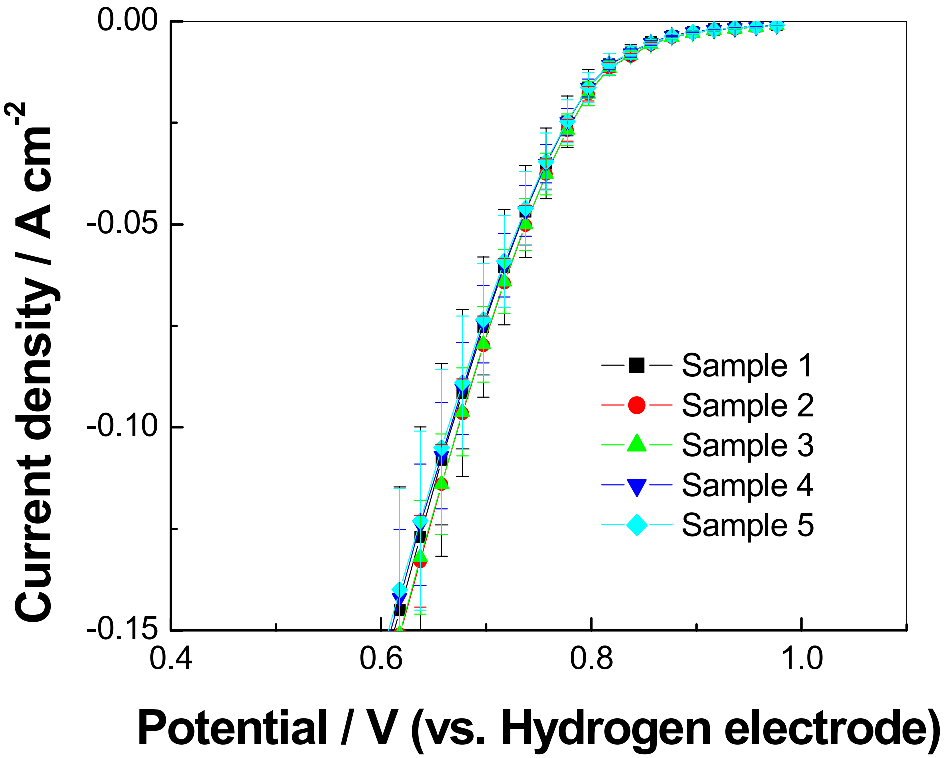
2. Complete measurements

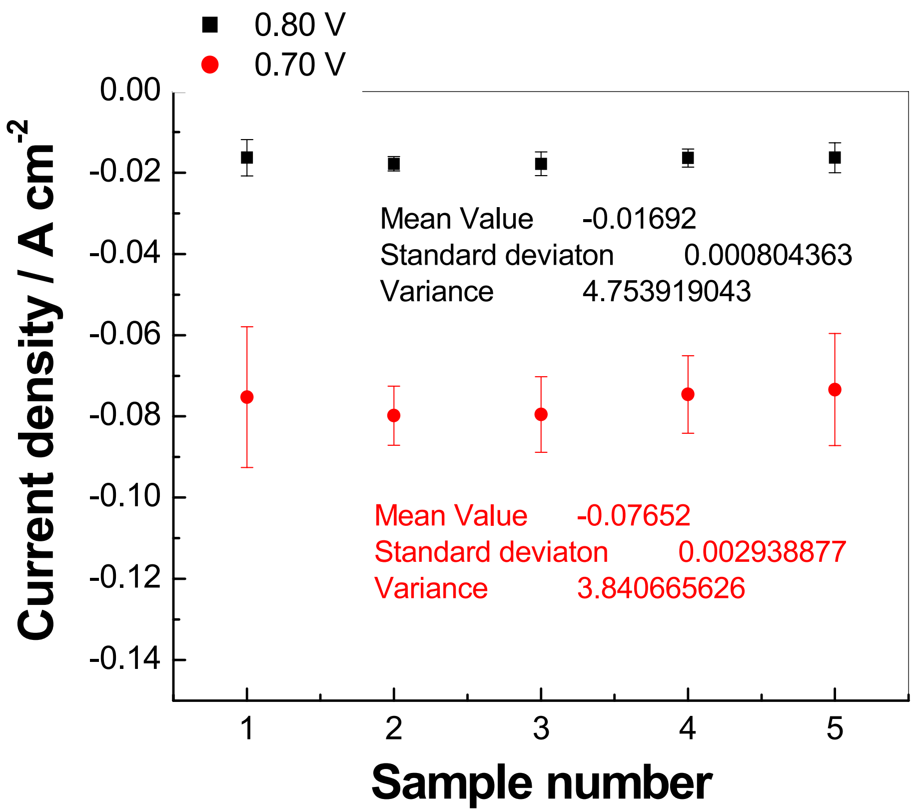
(a) Overall polarization curves at all 25 spots in kinetic zone. Note excessive spread at higher current densities.



(b) Data analyses

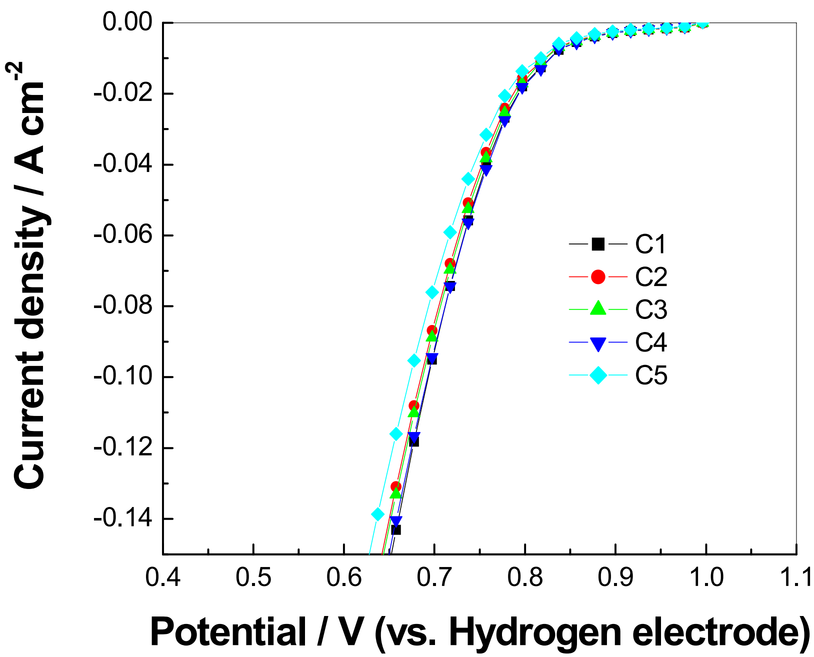
Left: Mean value curves in a Latin square
Right: Mean values at 0.80 and 0.70 V for each sample

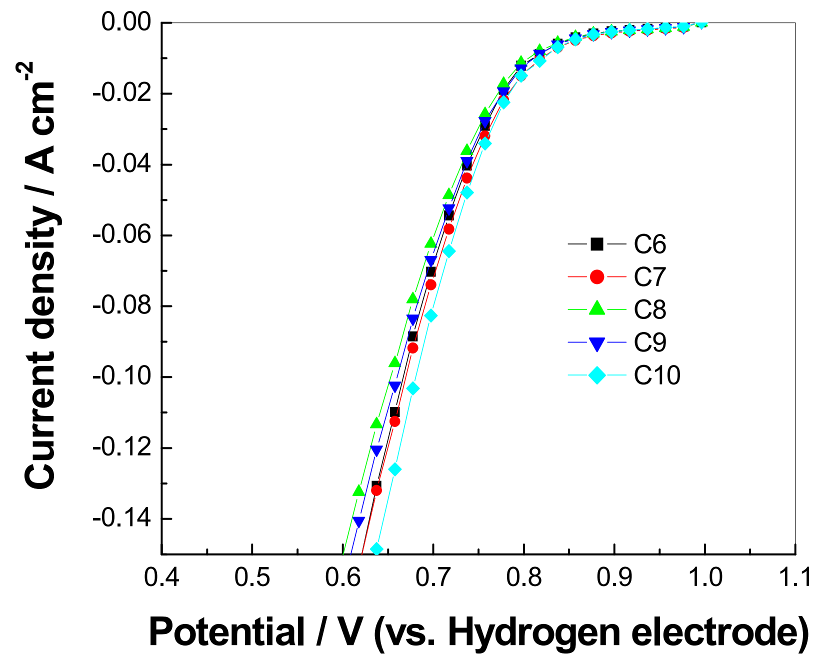




3. Partial screening experiments

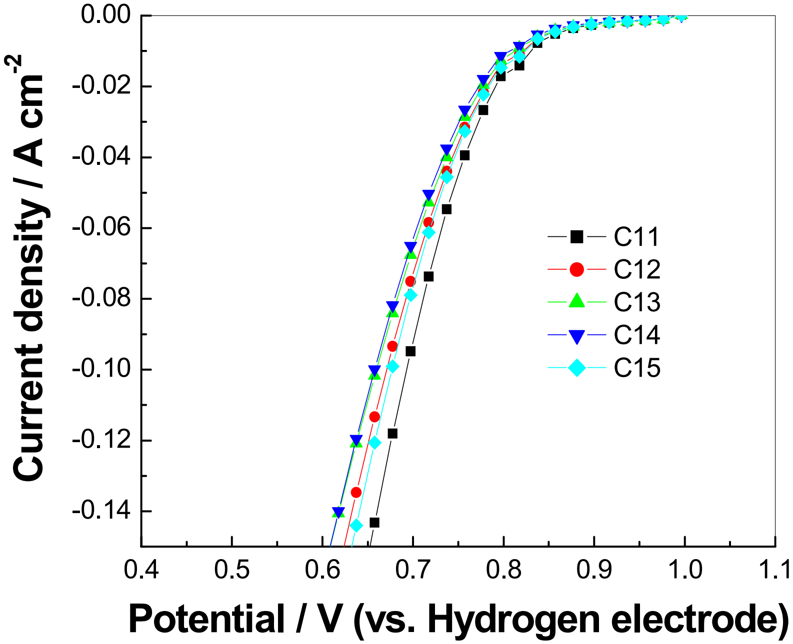
(a) Column switching (raw data for each column)

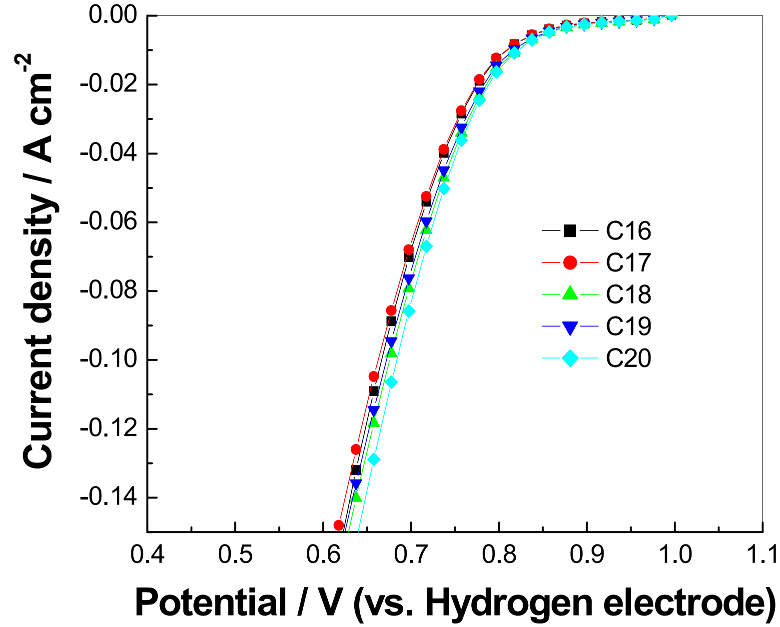




Column 1

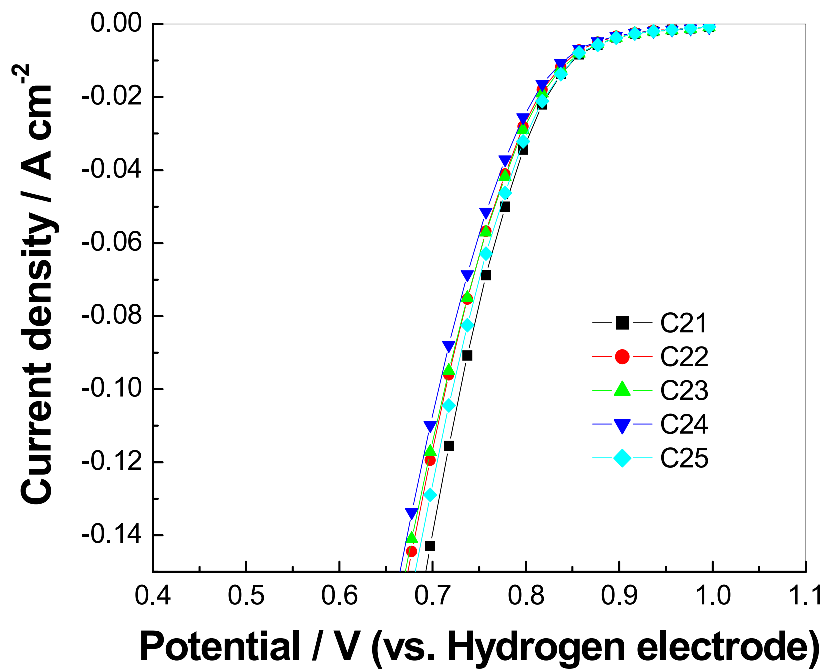
Column 2





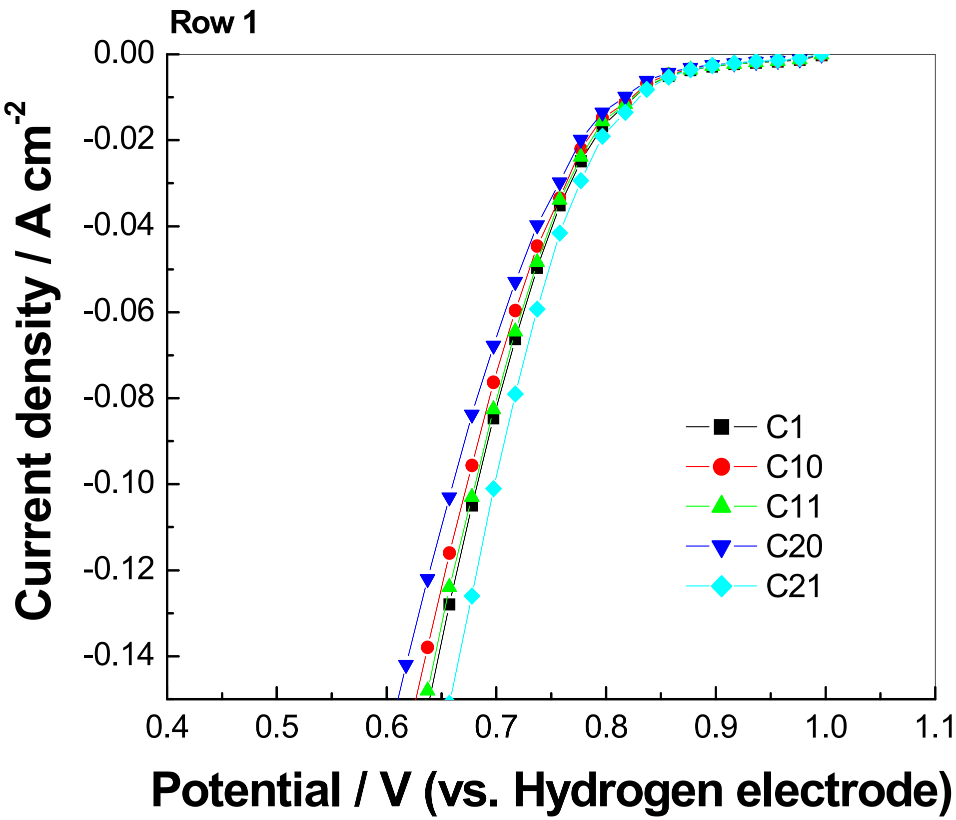
Column 3

Column 4

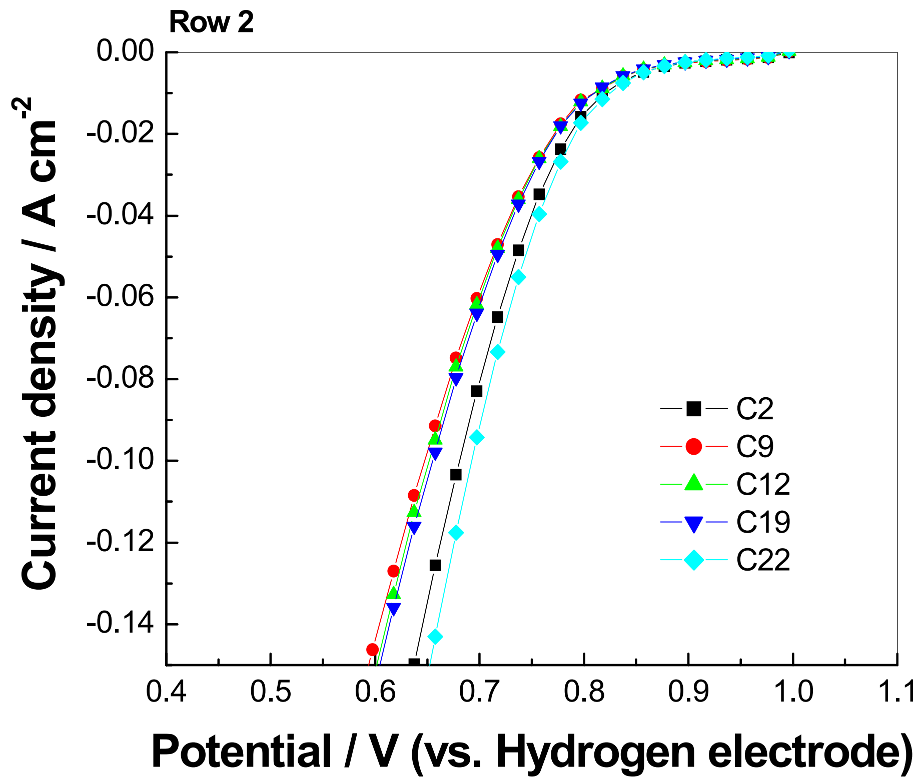


Column 5

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



Row 1



Row 2

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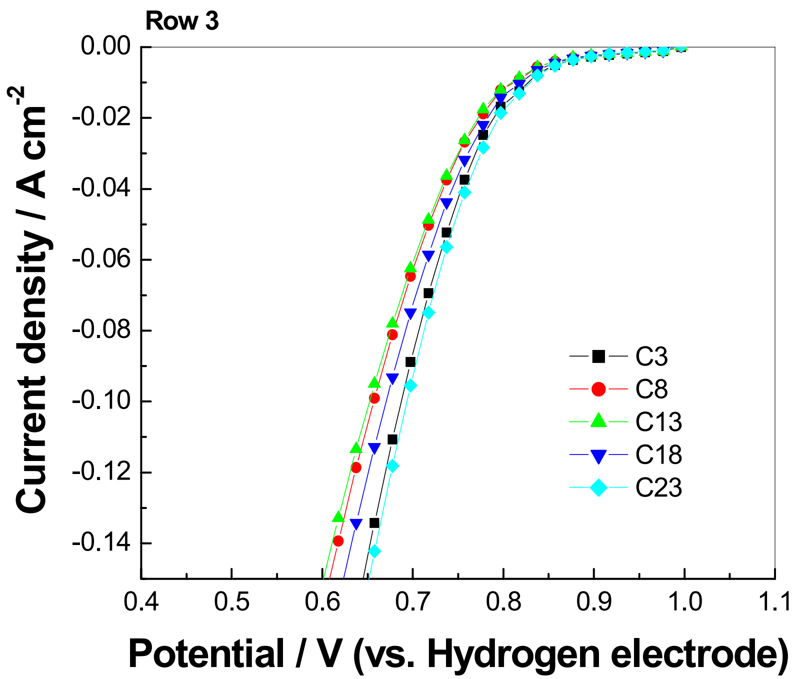
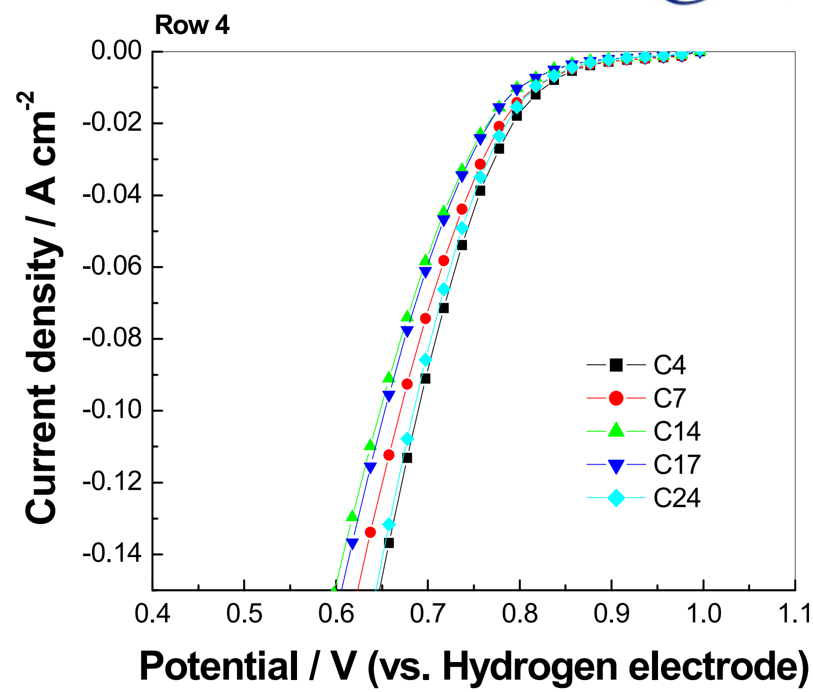
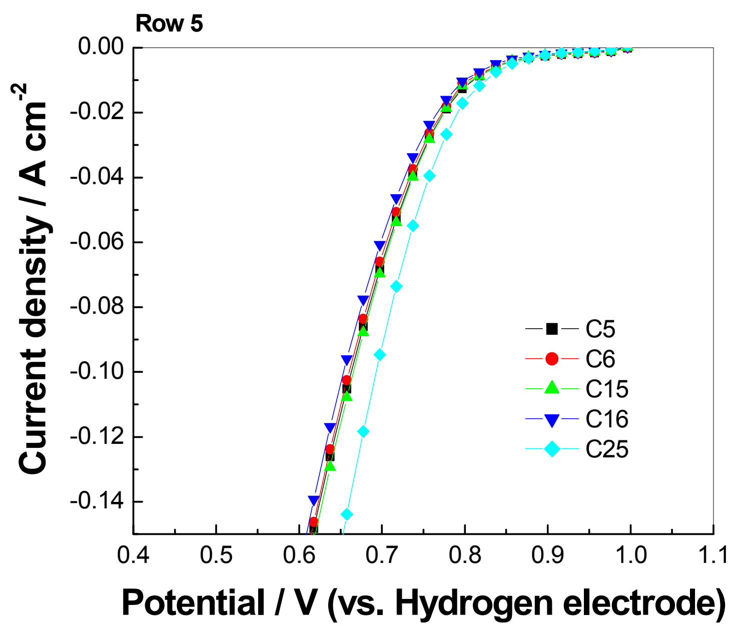




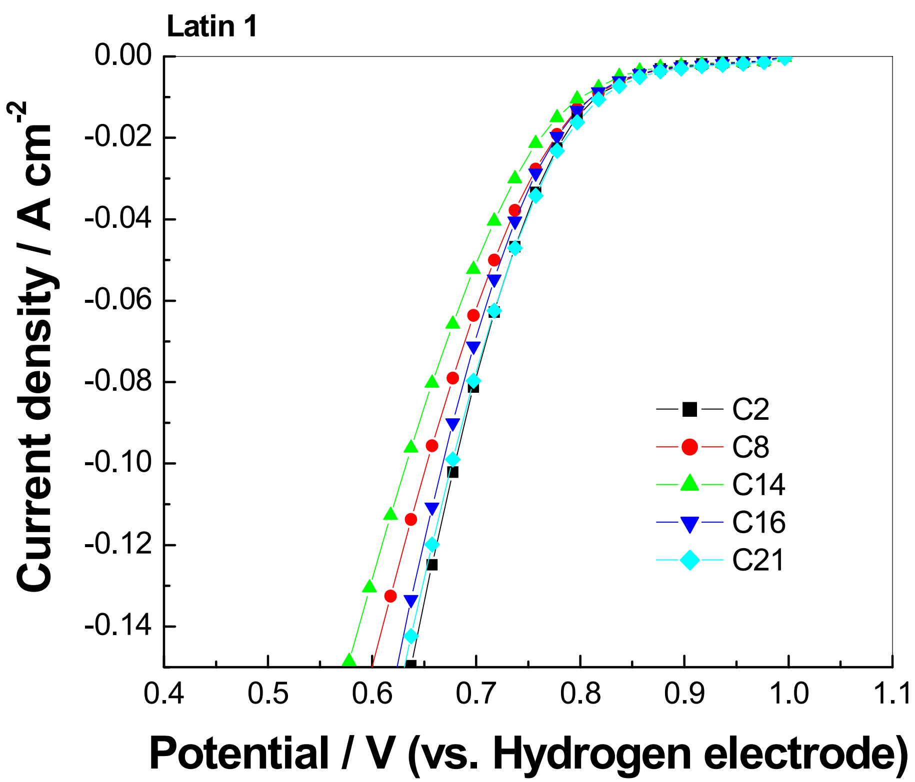
Row 3

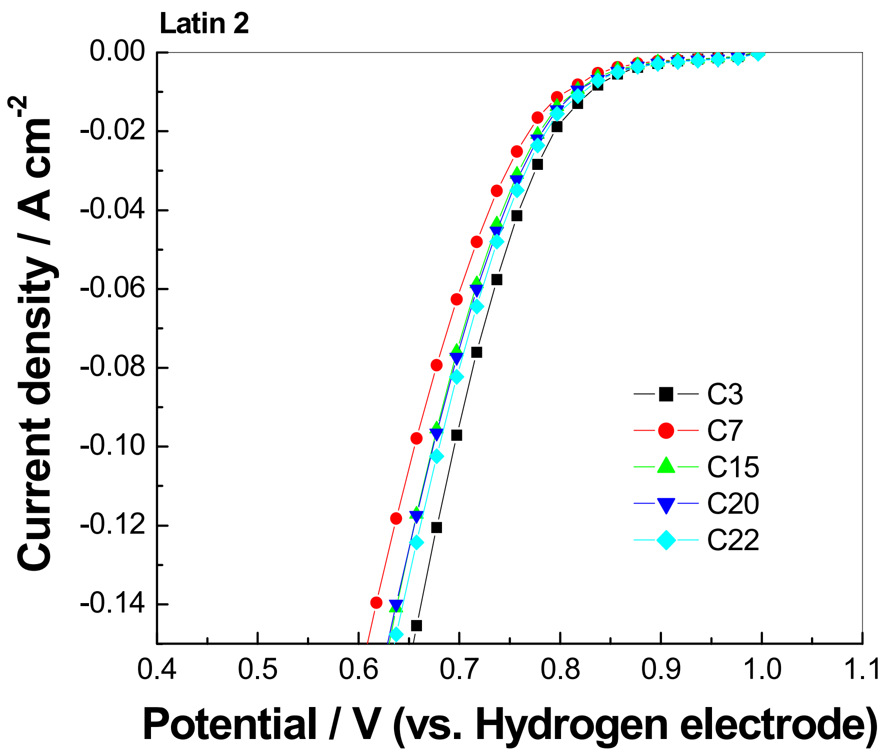


Row 4

Row 5

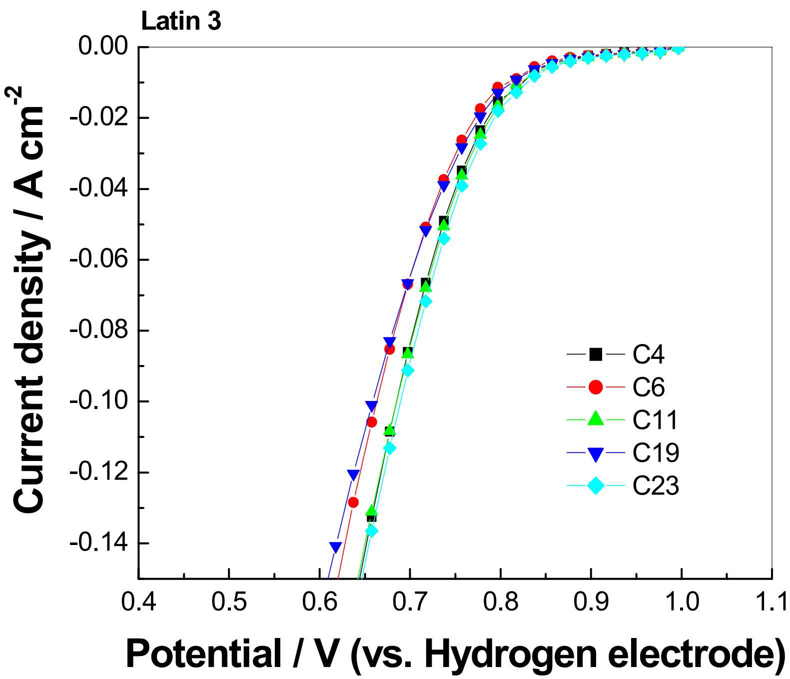
(c) Latin switching (raw data for each sample number in a Latin Square)

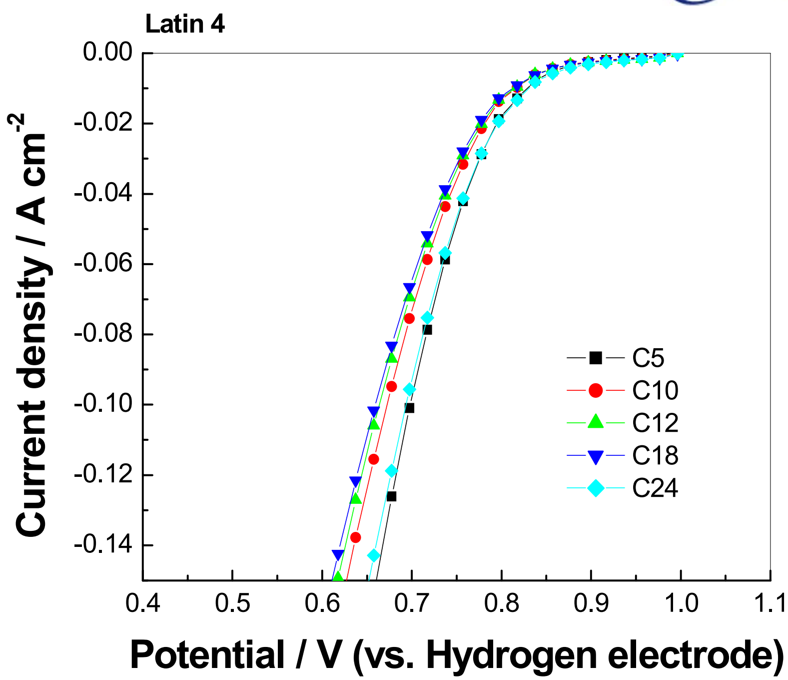




1 in Latin Square

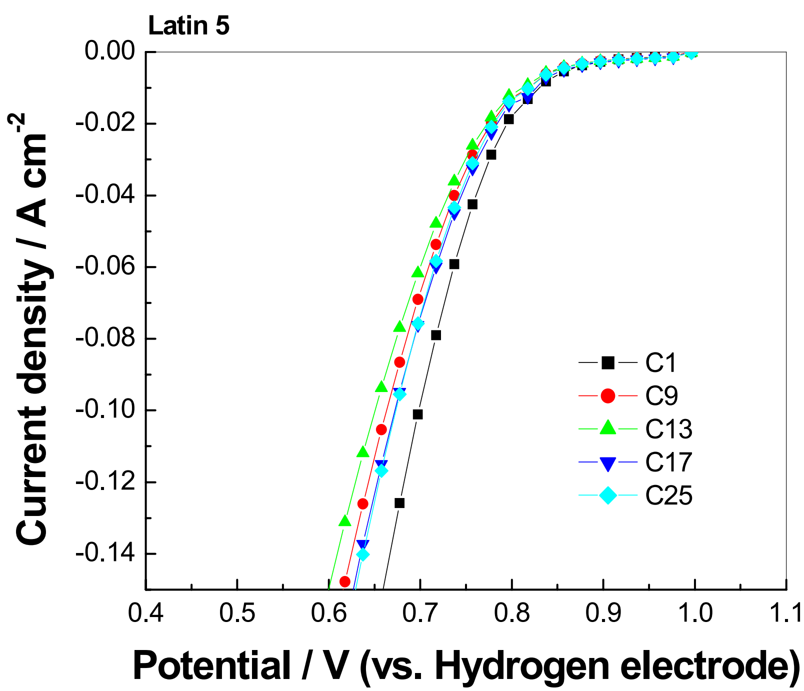
2 in Latin Square





3 in Latin Square

4 in Latin Square

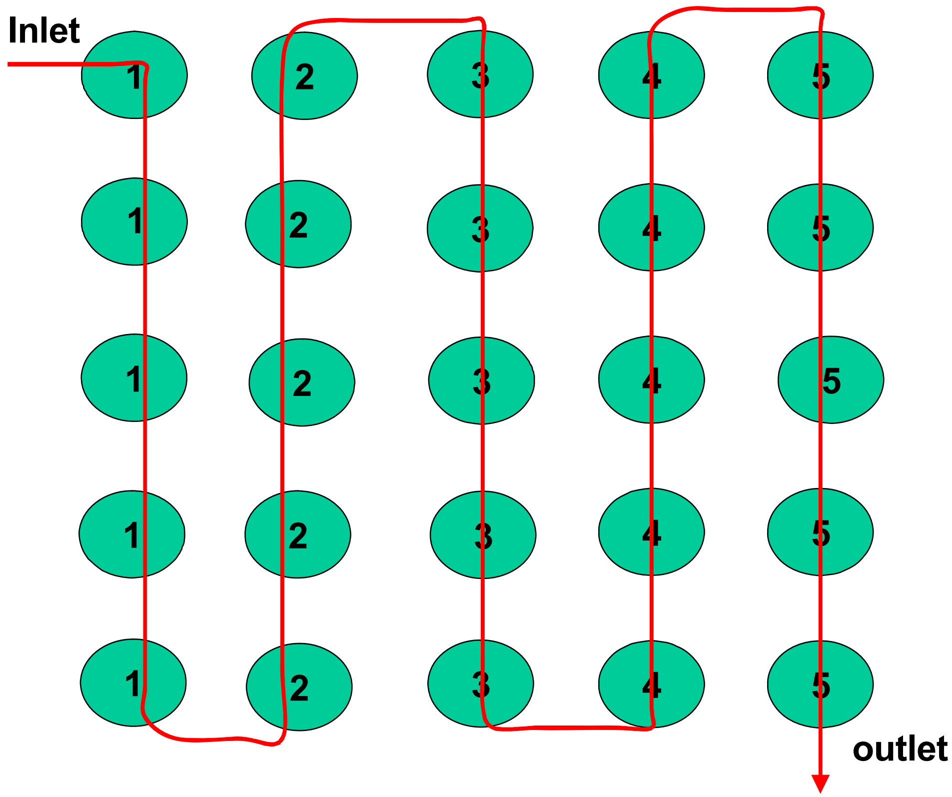


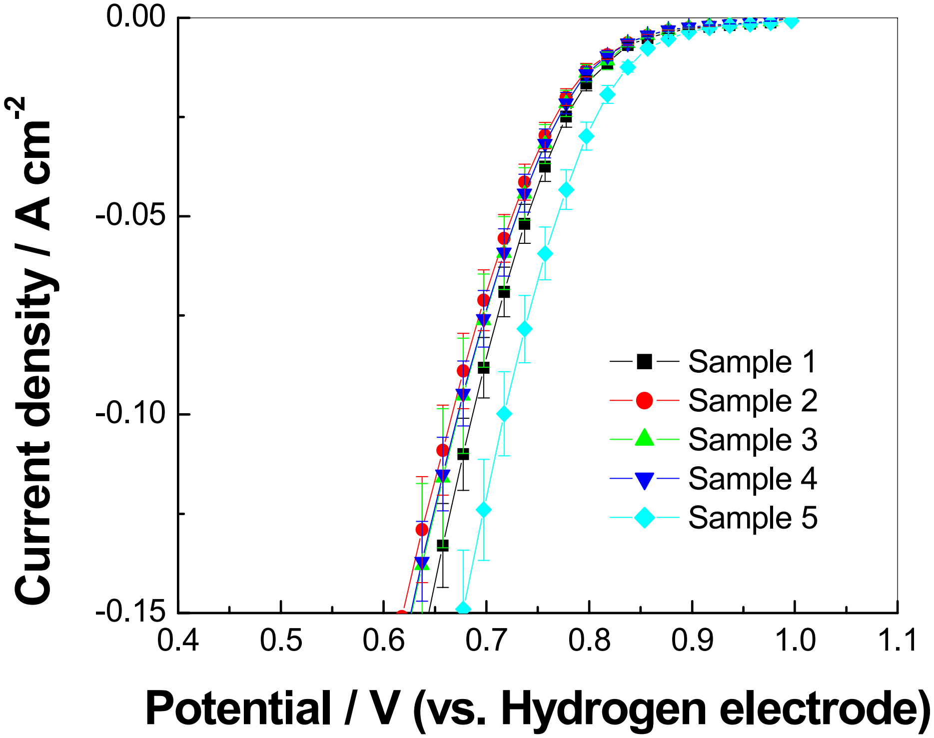
5 in Latin Square

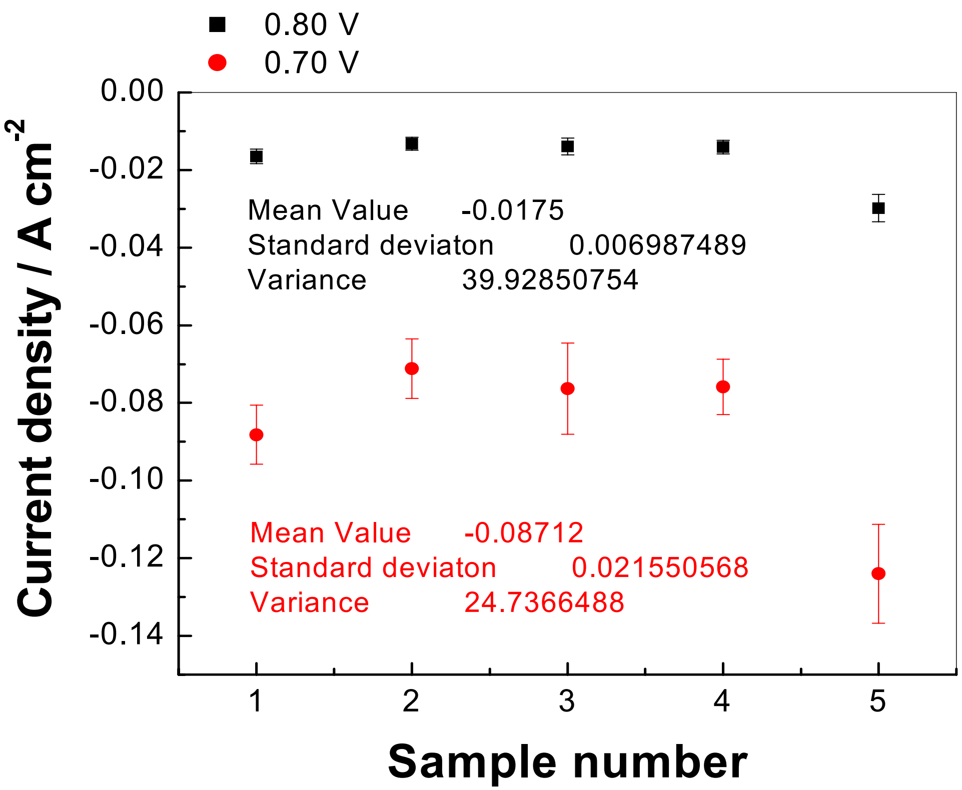
4. Data analyses for partial matrix measurements

(a) Column switching

Strategy 1: One sample lot per column





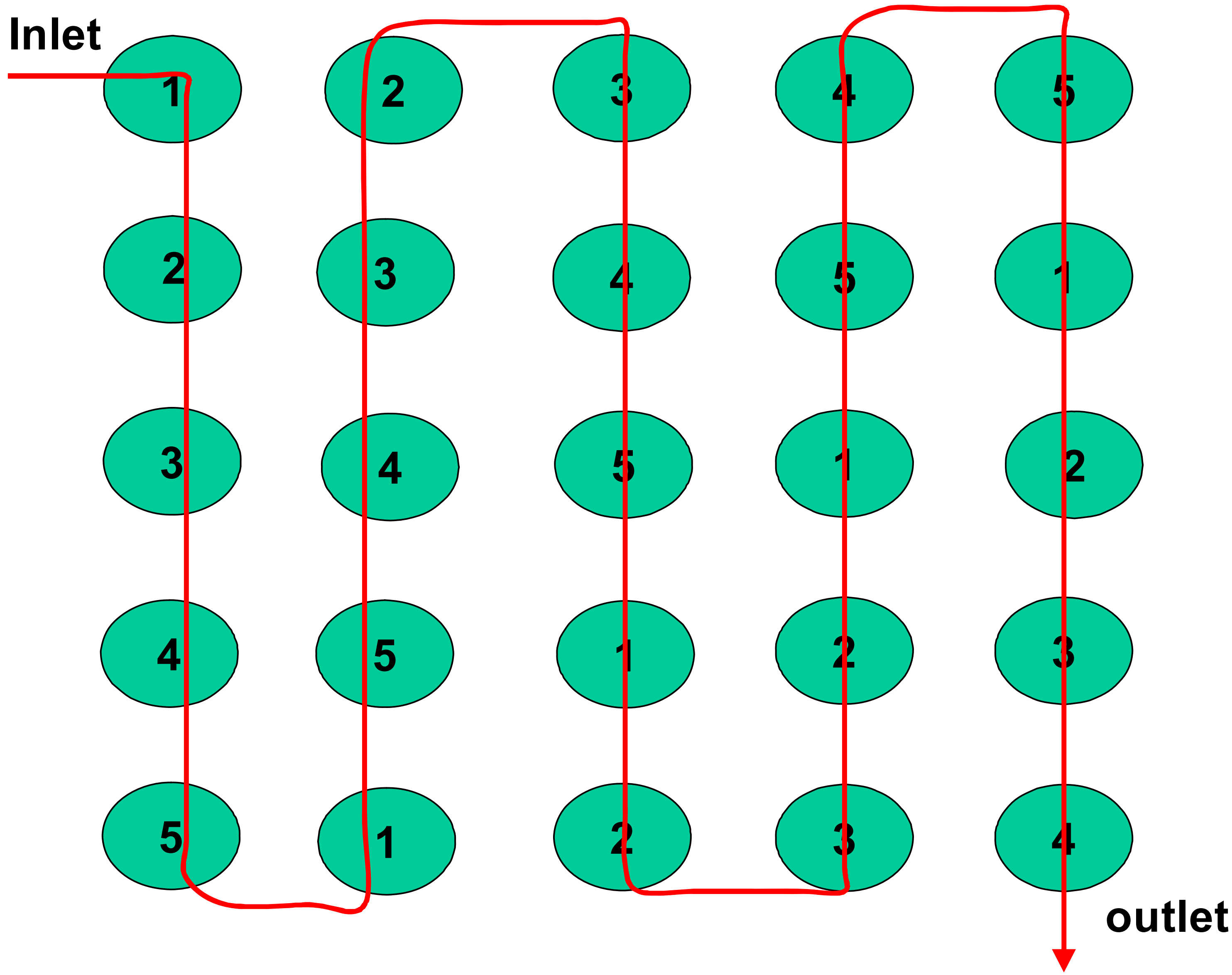


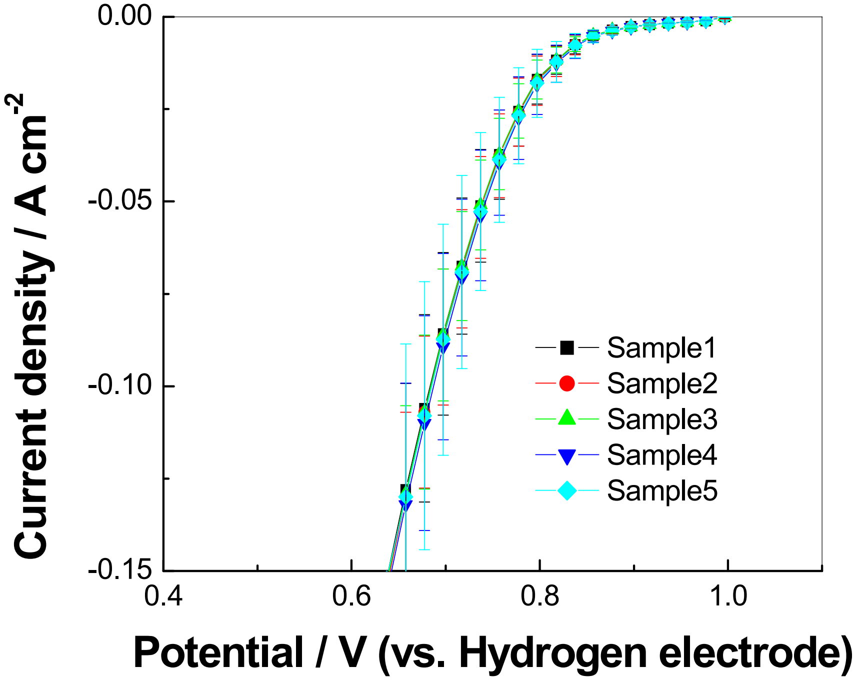
Mean value curves

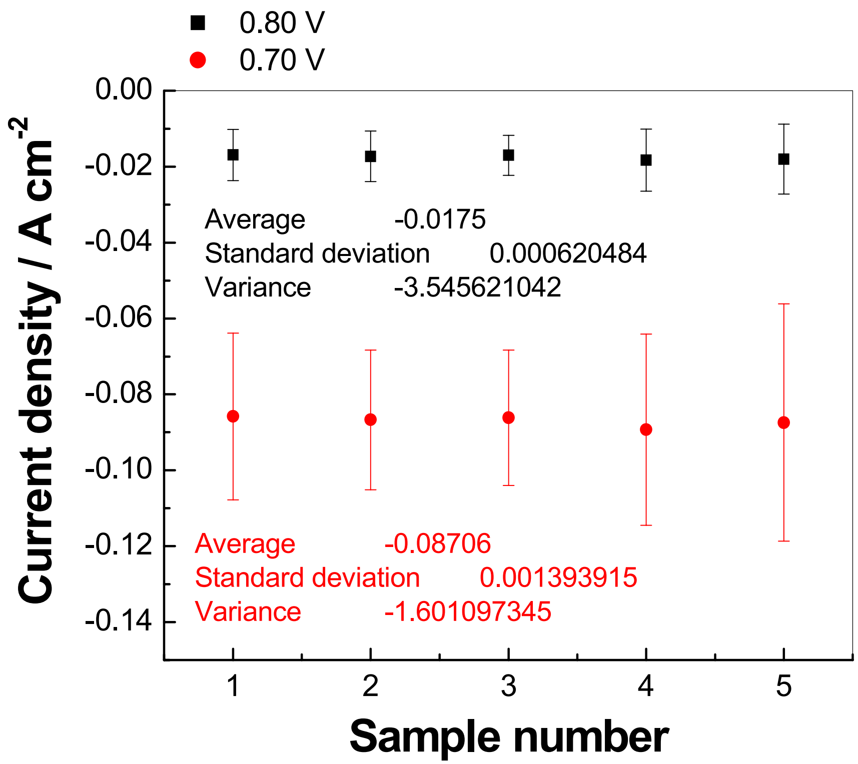
Mean values at 0.80 and 0.70 V for each sample

Comments: Strategy 1 – excessive spread

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







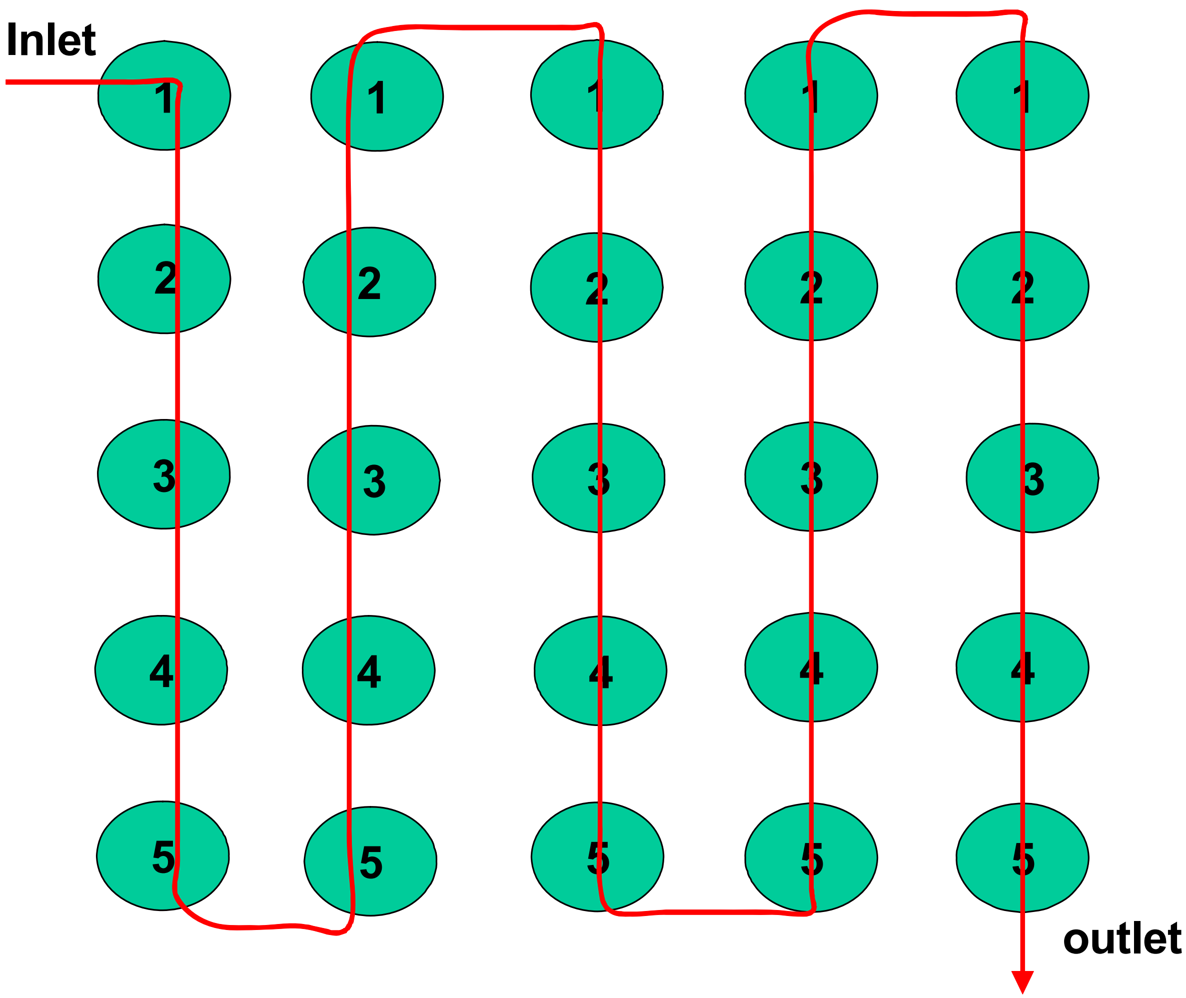
Mean value curves

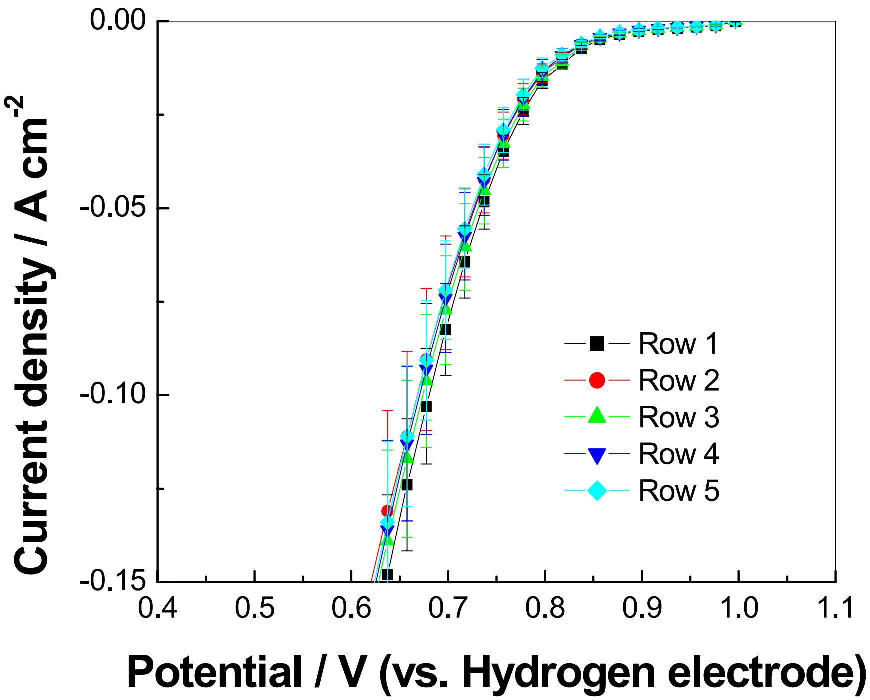
Mean values at 0.80 and 0.70 V for each sample

Comments: Strategy 2 – substantial reduction of spread

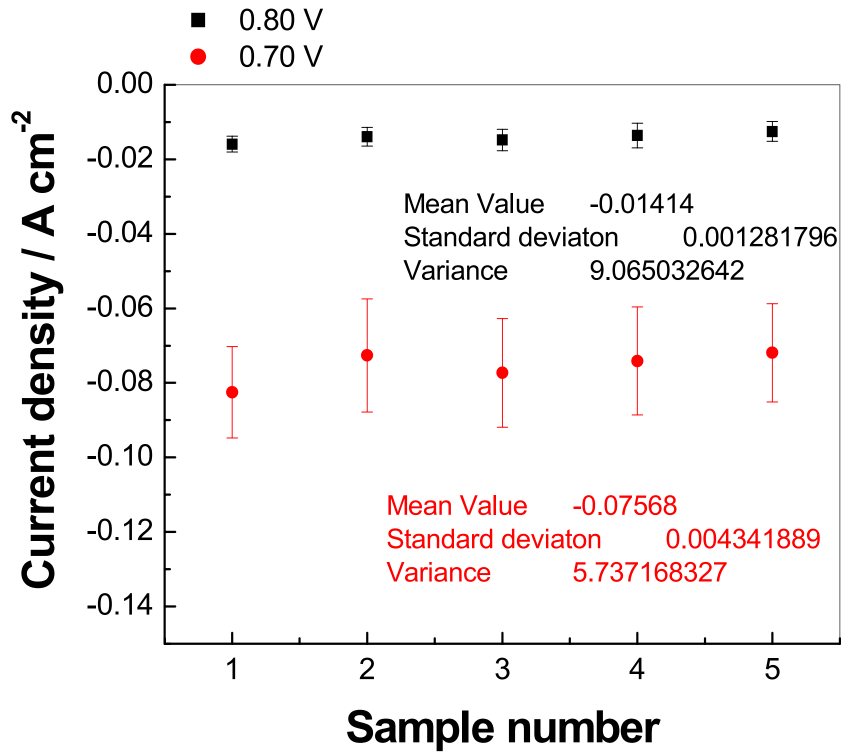
(b) Row switching

Strategy 3: One sample lot per row





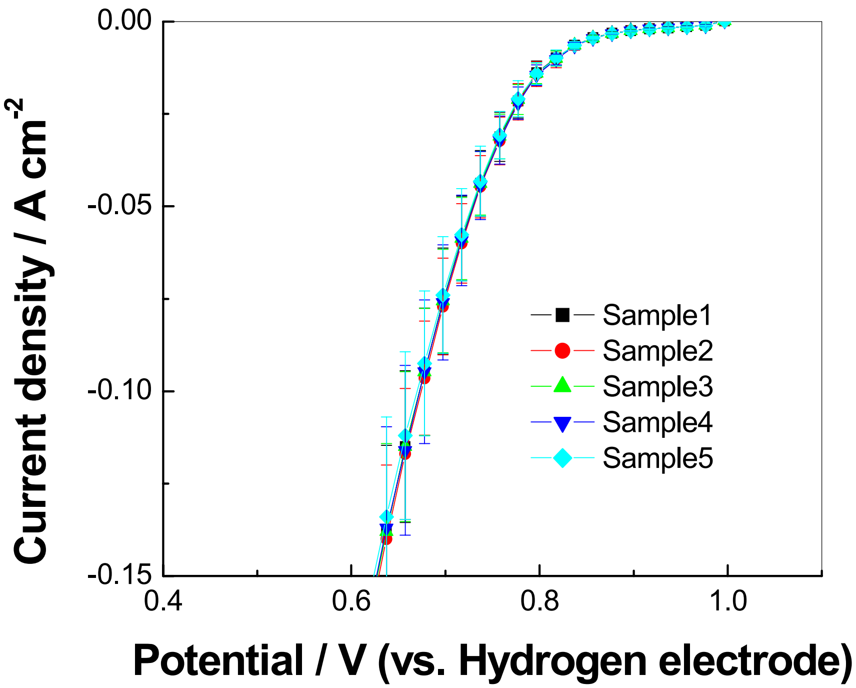
Mean value curves



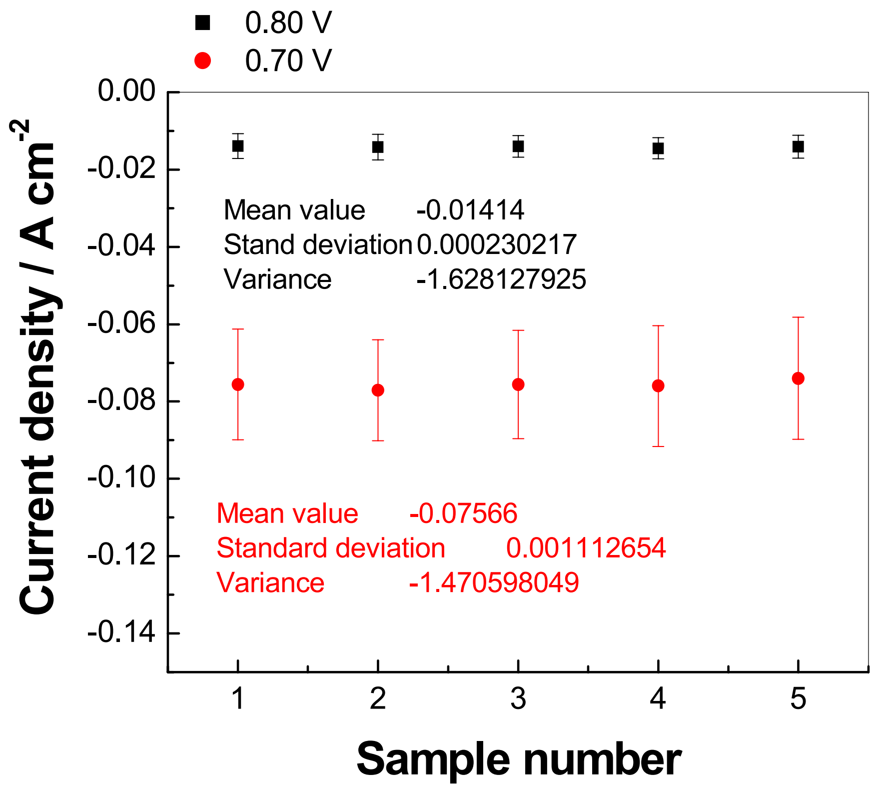
Mean values at 0.80 and 0.70 V for each sample

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

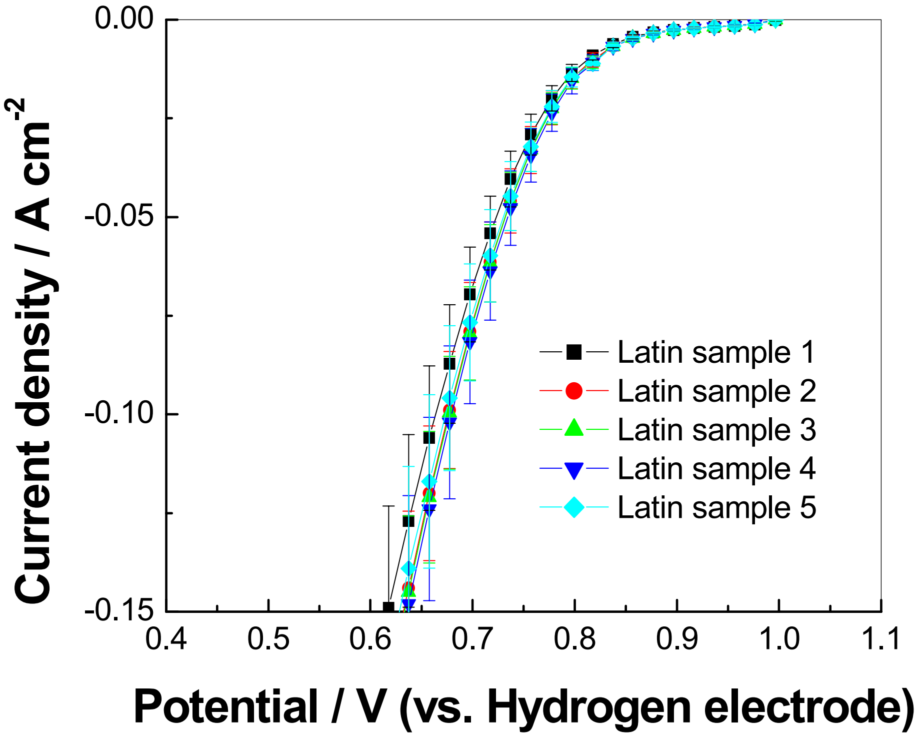


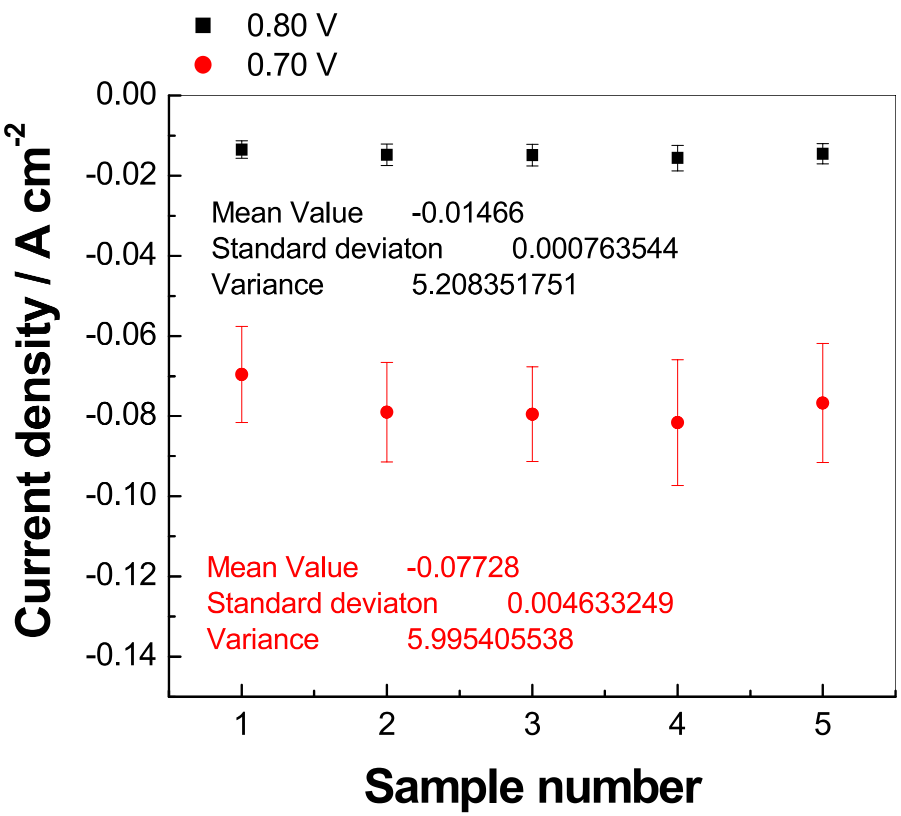
Mean values at 0.80 and 0.70 V for each sample

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

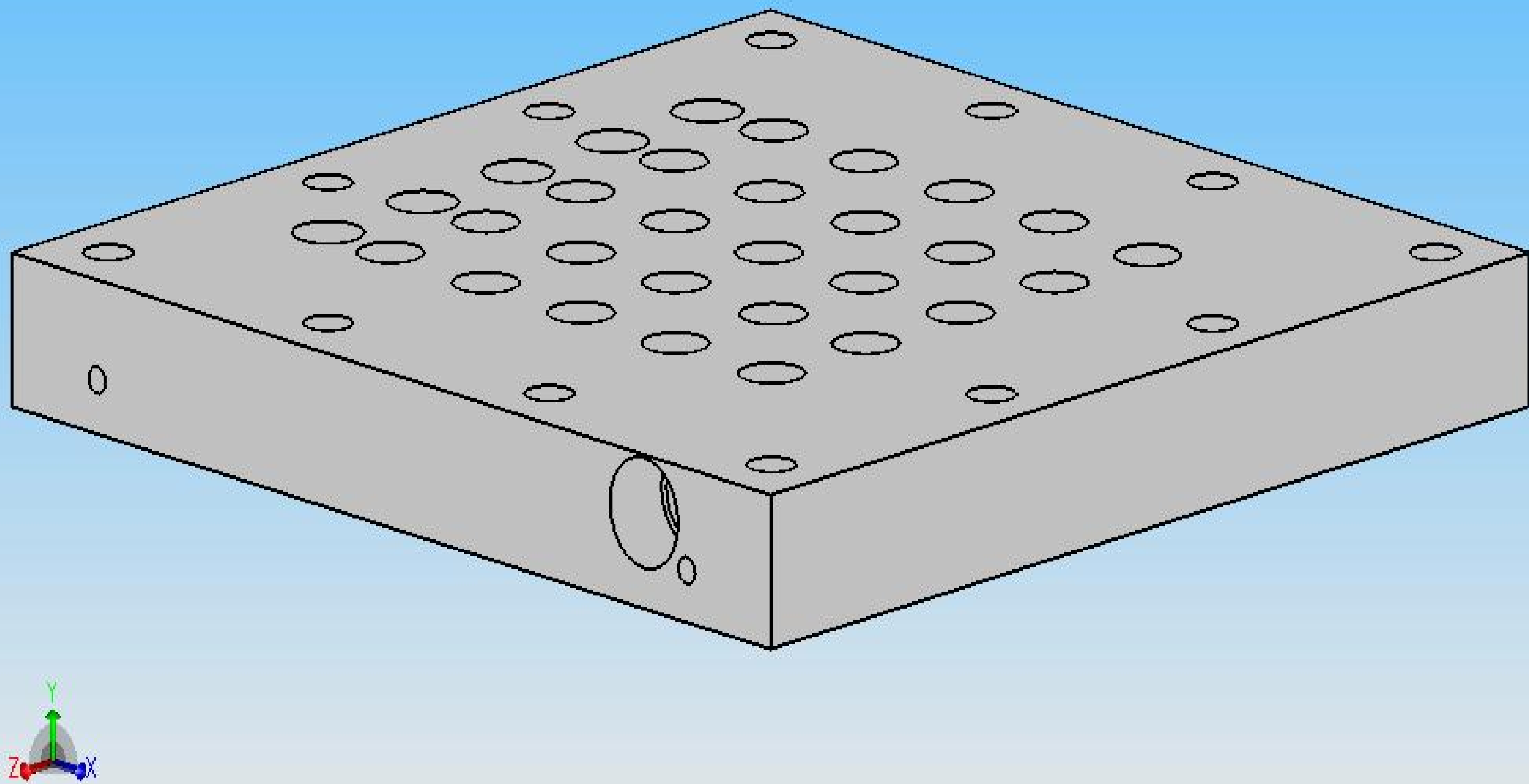
- Partial matrix screening (i.e. row and column switching) shows advantages over full matrix screening in terms of suppressing the spread of mean values for samples grouped in a Latin square.

- Row and column switching enhances Latin square analysis.

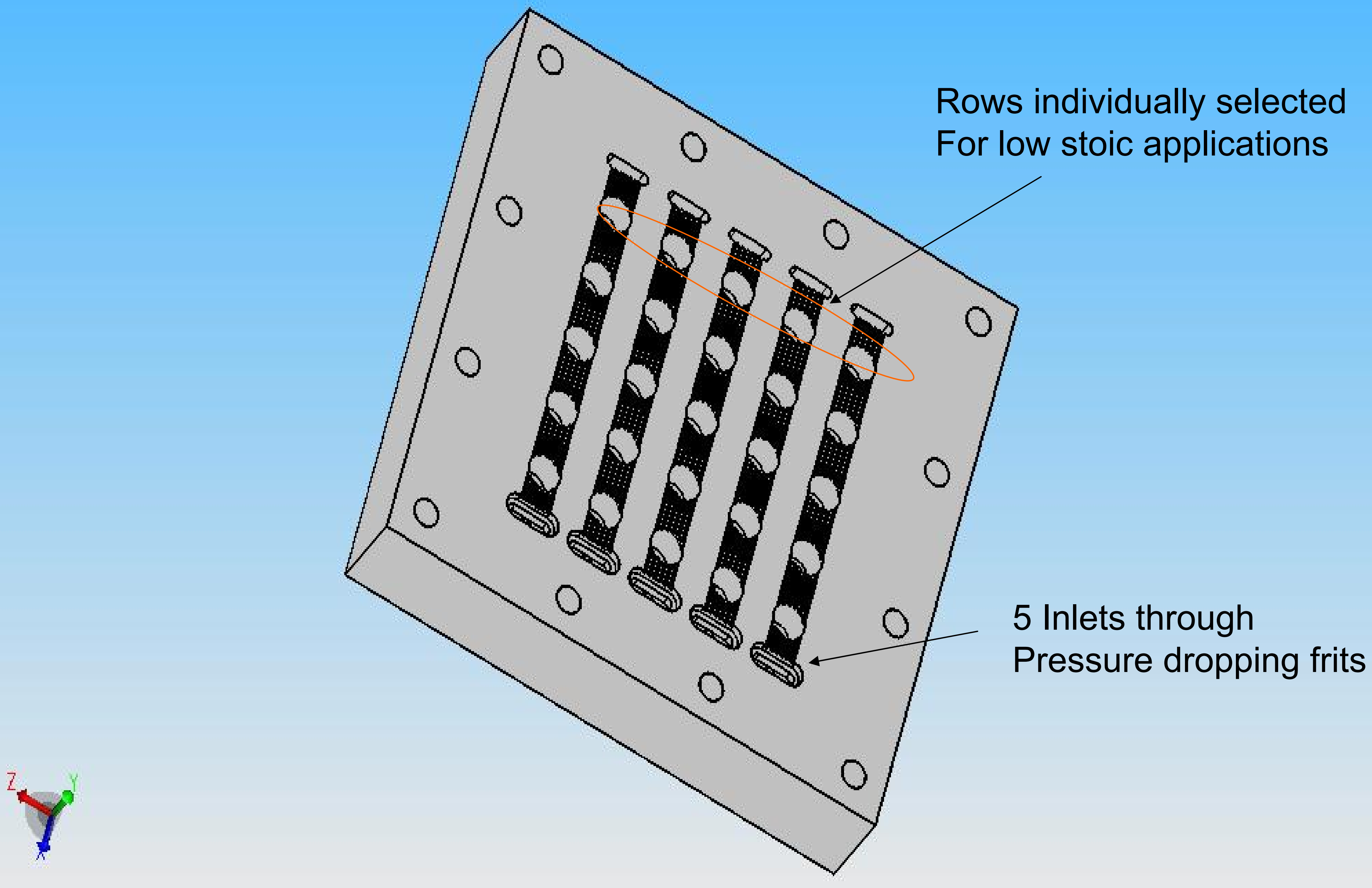
A new array flow field design is motivated by previous results

- 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

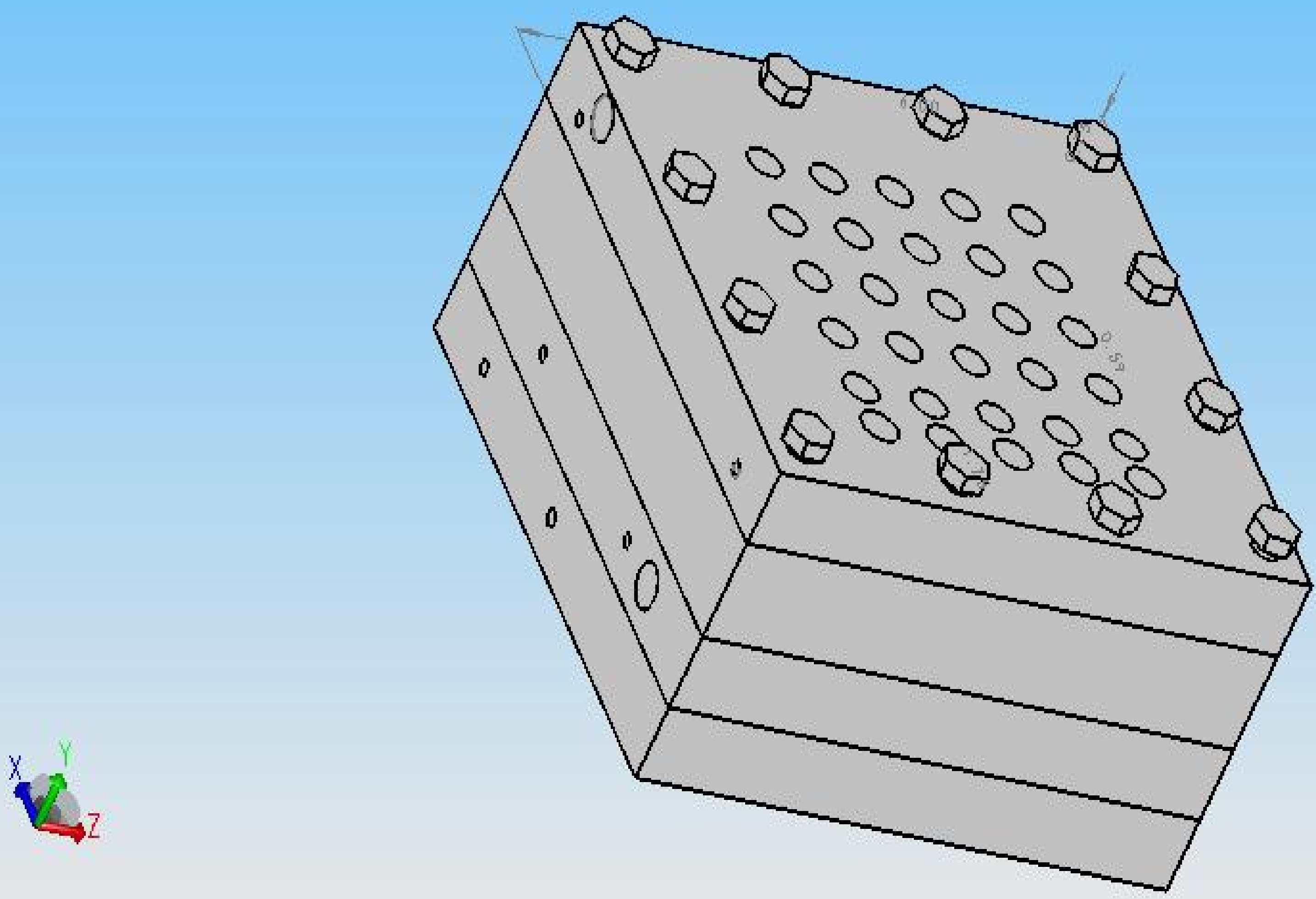


Parallel array flow field for optimized row and column switching at low stoic ratios.



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.