Development of Bifunctional Electrodes for Closed-loop Fuel Cell Applications

Electrochemistry 2010: From Microscopic Understanding to Global Impact

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Content

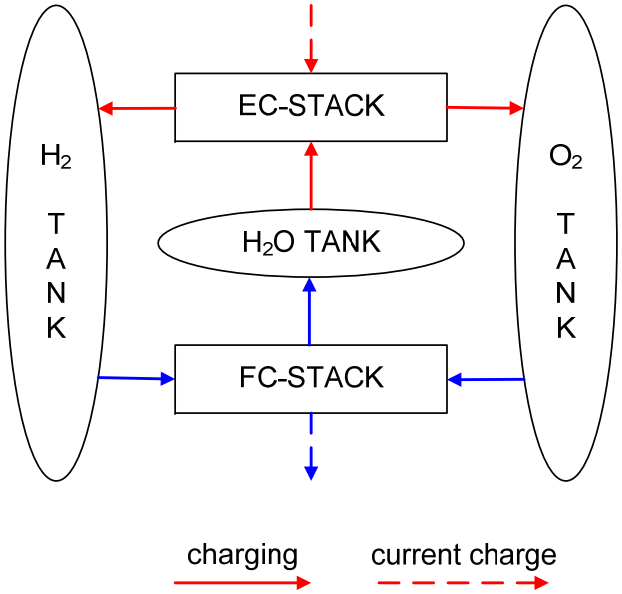
Introduction

- Advantages to secondary batteries
  - specific energy and energy density are higher then secondary batteries
  - modular
  - easy integration in existing systems (e.g. Ariane 5)
  - fast “recharging” option

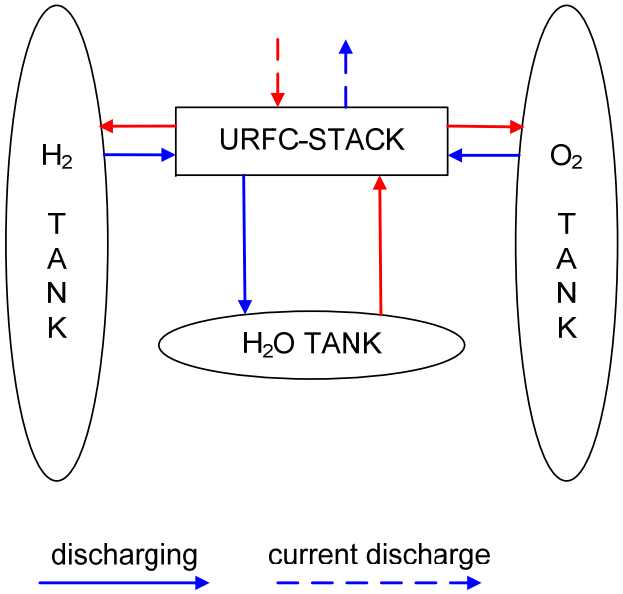
- Stand-alone systems without grid connection
  - manned (long-term) space missions
  - UAV (unmanned air vehicle)
  - local stationary energy supply

Regenerative Fuel Cell

Regenerative Fuel Cell (RFC)



Unitized Regenerative Fuel Cell (URFC)



☺ - optimized catalysts
- changing operation mode more easier (e.g. no time delay)

☹ - high mass
- high volume

☺ - reduced mass and volume
- cost reduction
- increased reliability (less components)

☹ - different catalyst on one electrode
- changing conditions at MEA

Preparation

- Dry-Spraying-technique by DLR

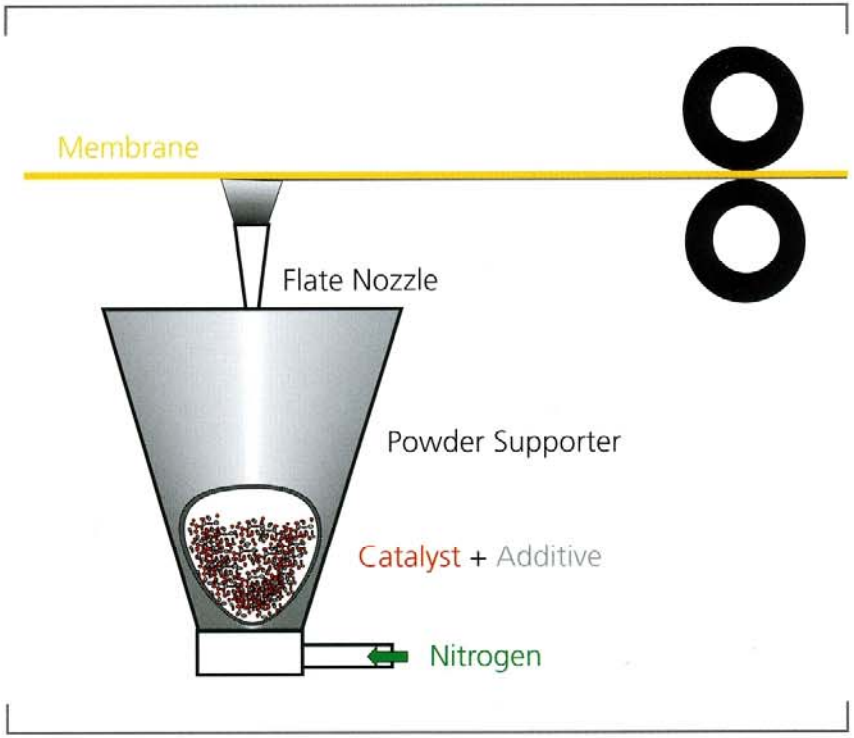


Figure 1: Principle of dry coating method for electrode production

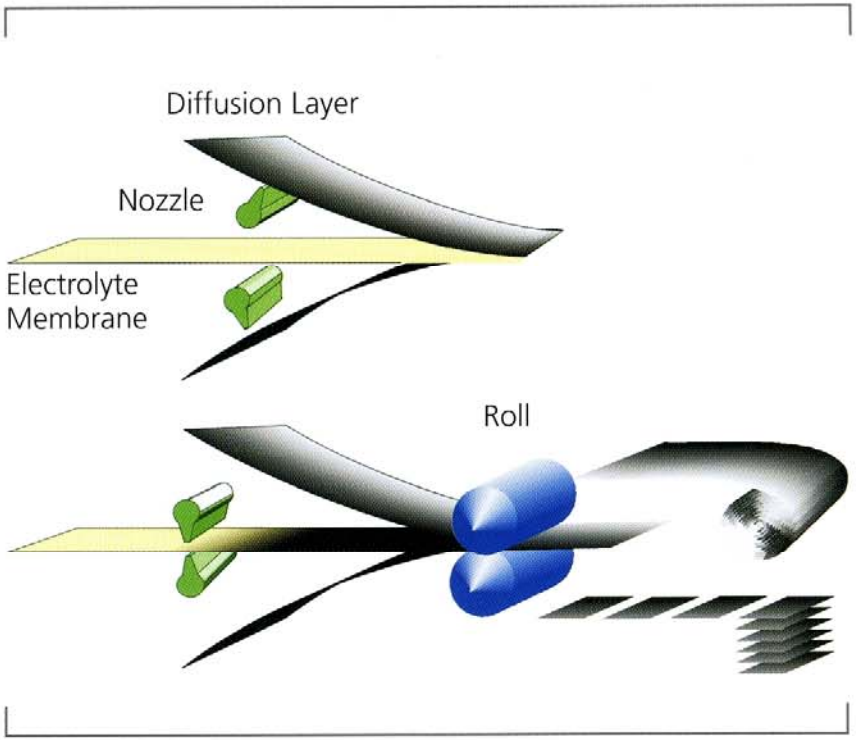


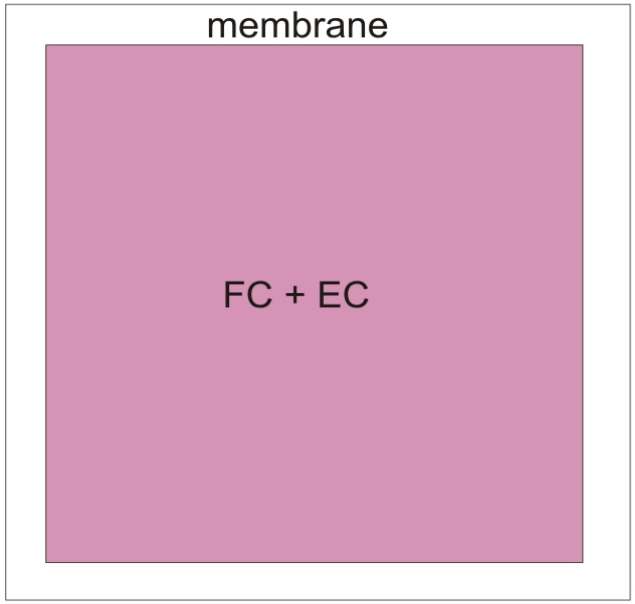
Figure 2: Production of membrane electrode assemblies by dry spray coating. Two alternative methods are shown.

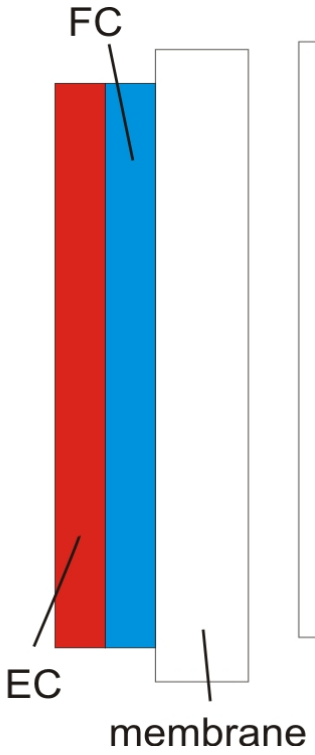
Preparation

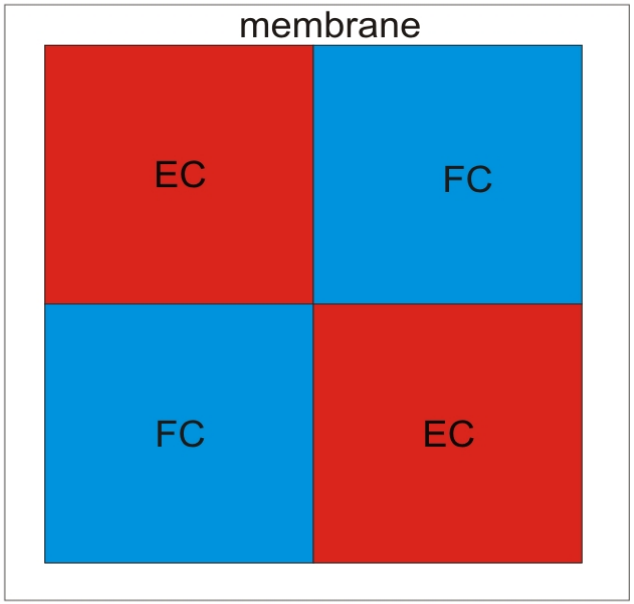
- fast (no evaporation of solvent, no ink preparation)
- simple (few steps in preparation)
- flexible
  - several mixture of catalysts and additives
  - different kind of electrodes (DMFC, PEFC,…)
  - various thickness
  - different loadings
  - various geometries of the electrodes
  - coating directly on membrane

MEA-Development

Overview







option 1
mixture of catalysts

option 2
multilayer electrode

option 3
segmented active area

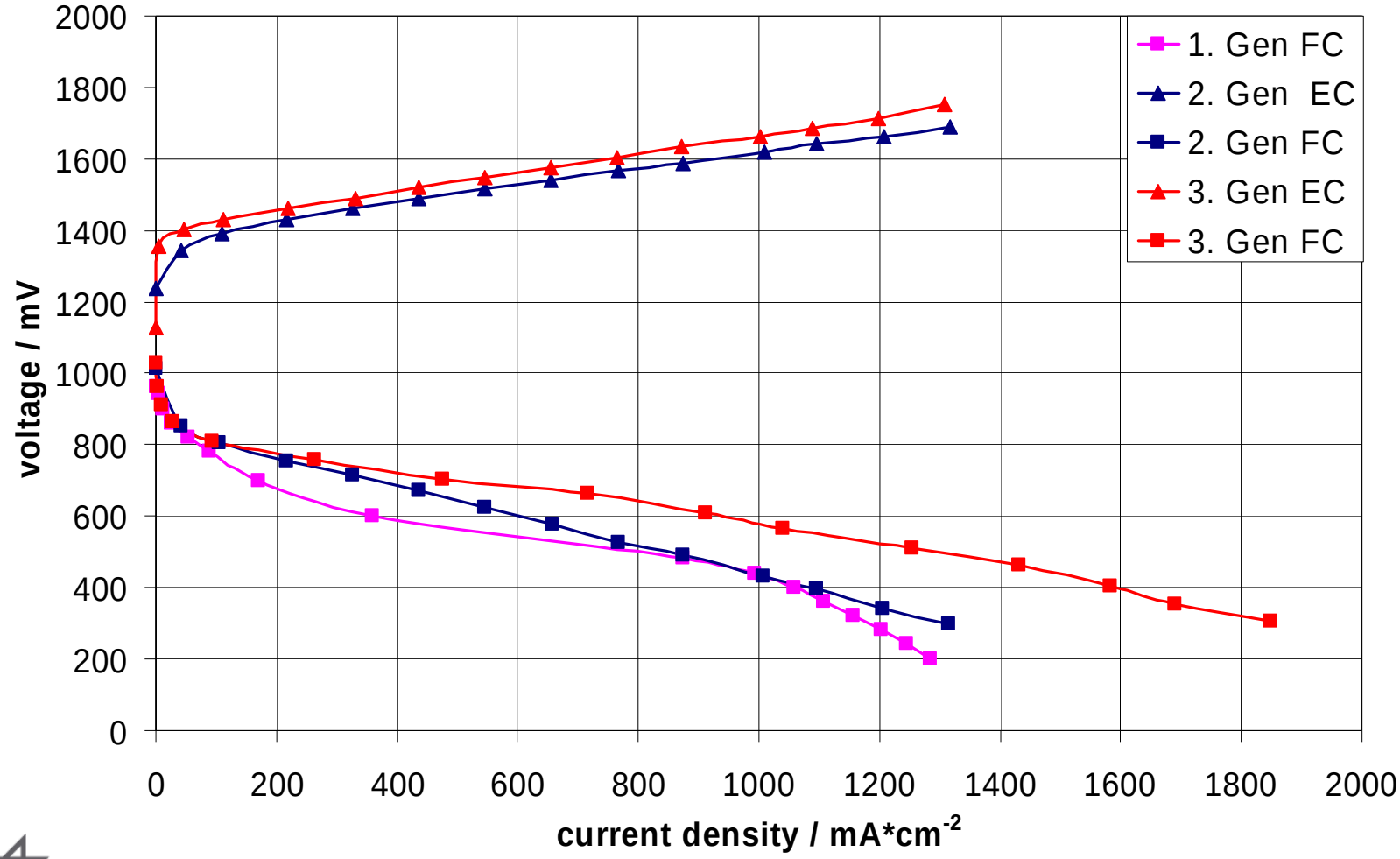
MEA Development

option 1 – mixture of catalysts

- 3 generation
  - 1st generation — H_2: supported Platinum (20 wt% Pt); O_2: IrO_2 + Pt black (ration 1:1)
  - 2nd generation — H_2: Pt black; O_2: IrO_2 + Pt black (ratio 1:1)
  - 3rd generation — H_2: Pt black; O_2: IrO_2 + Pt black (ratio 3:7)
- <u>loading</u> — H_2: ~ 0.6 to 0.8 mg/cm²; O_2: ~ 1.5 to 1.8 mg/cm²; 30 wt% Nafion

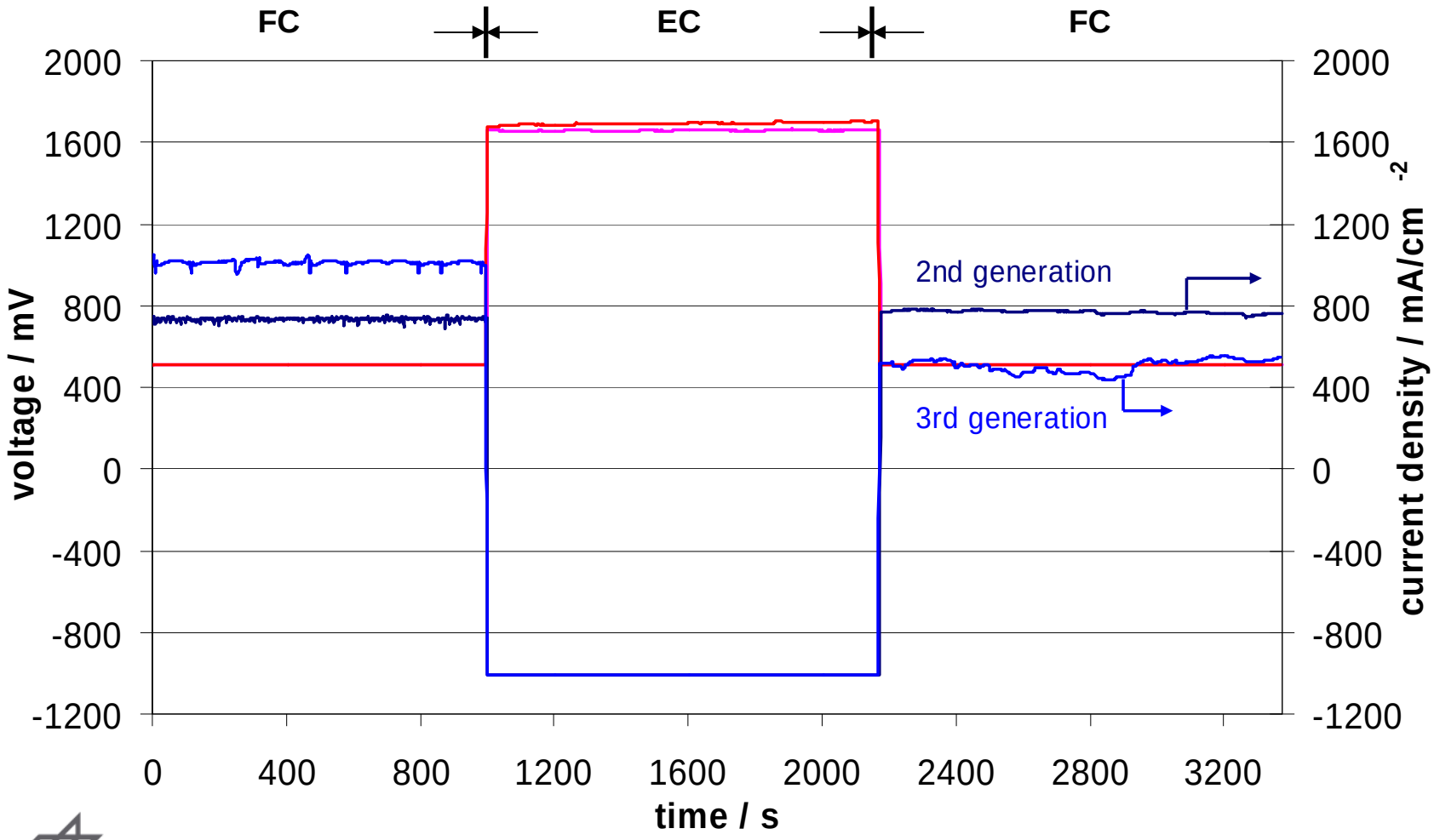
MEA Development

option 1 – mixture of catalysts



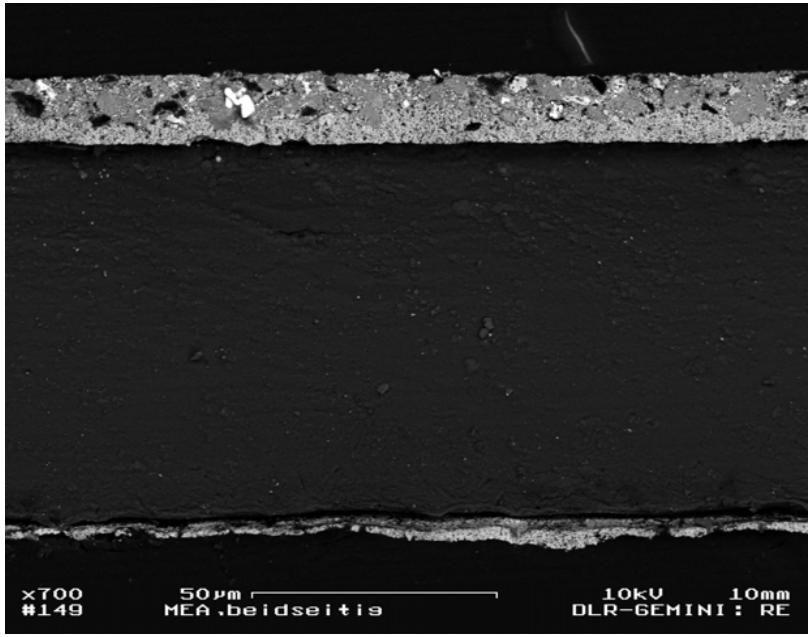
MEA Development

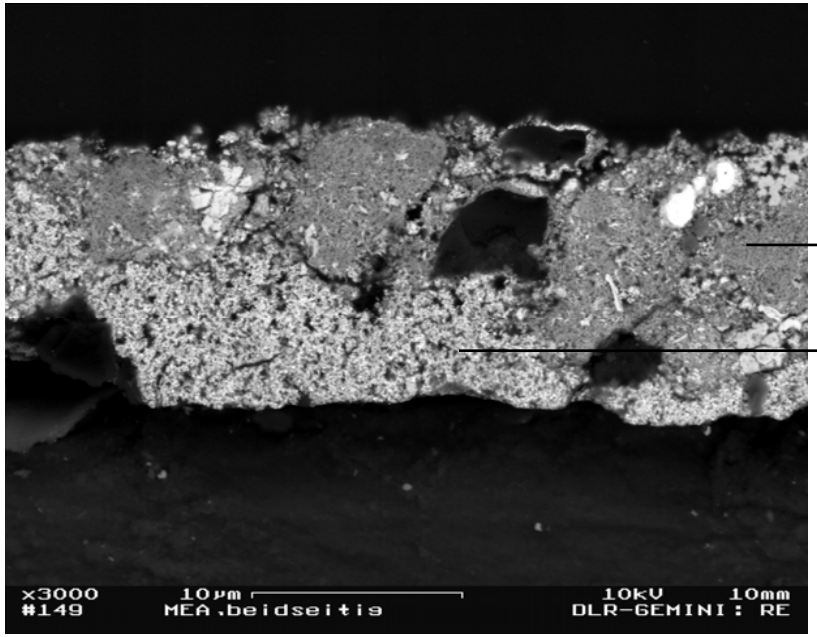
option 1 – mixture of catalysts



MEA Development

option 2 – multilayer electrode





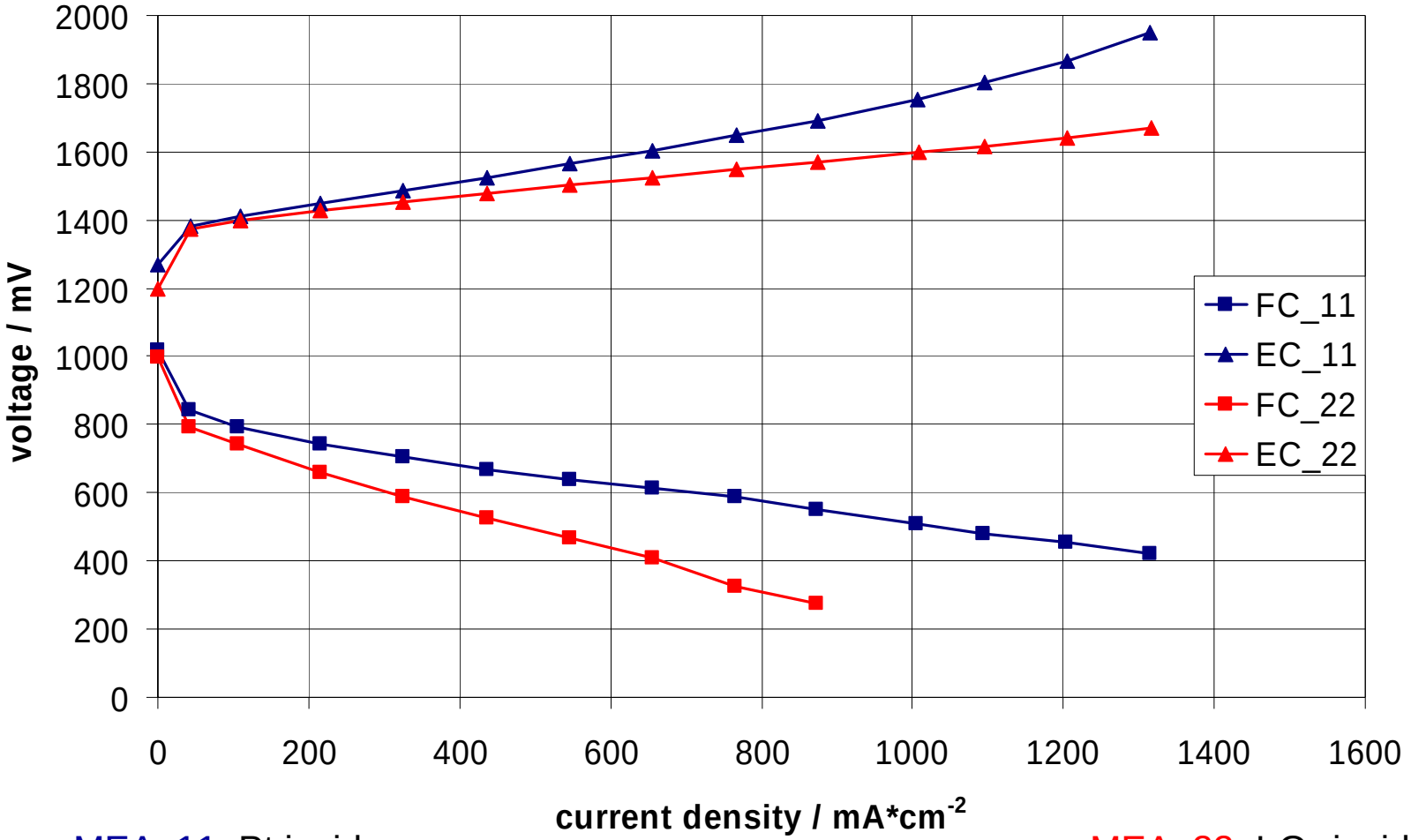
catalysts: H_2: Pt black + 30 wt% Nafion (loading ~ 0.7 mg/cm²)

O_2: IrO_2 + 30 wt % Nafion (EC) (loading ~ 0.9 mg/cm²)

Pt black + 30 wt% Nafion (FC) (loading ~ 0.8 mg/cm²)

MEA Development

option 2 – multilayer electrode



MEA_11: Pt inside

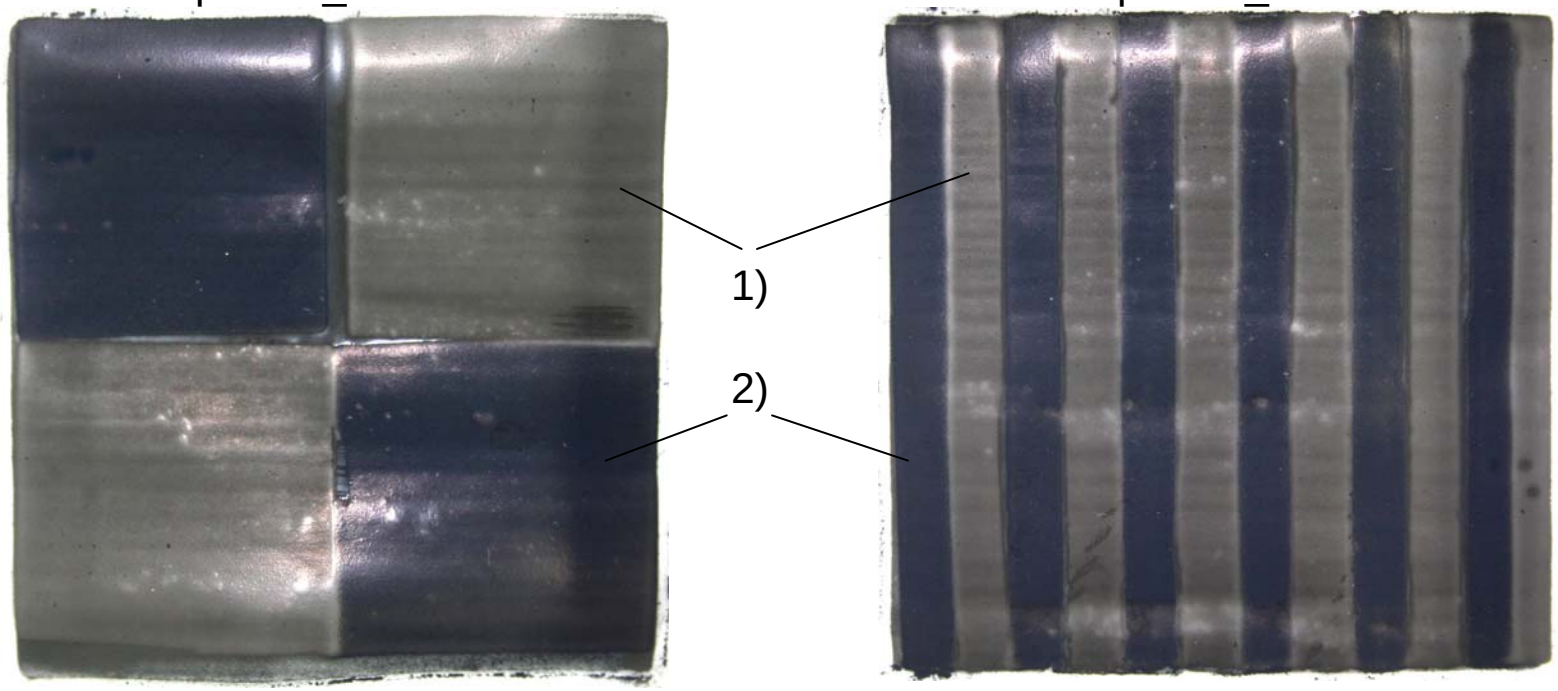
MEA_22: IrO_2 inside

MEA Development

option 3 – segmented active area

option 3_1

option 3_2



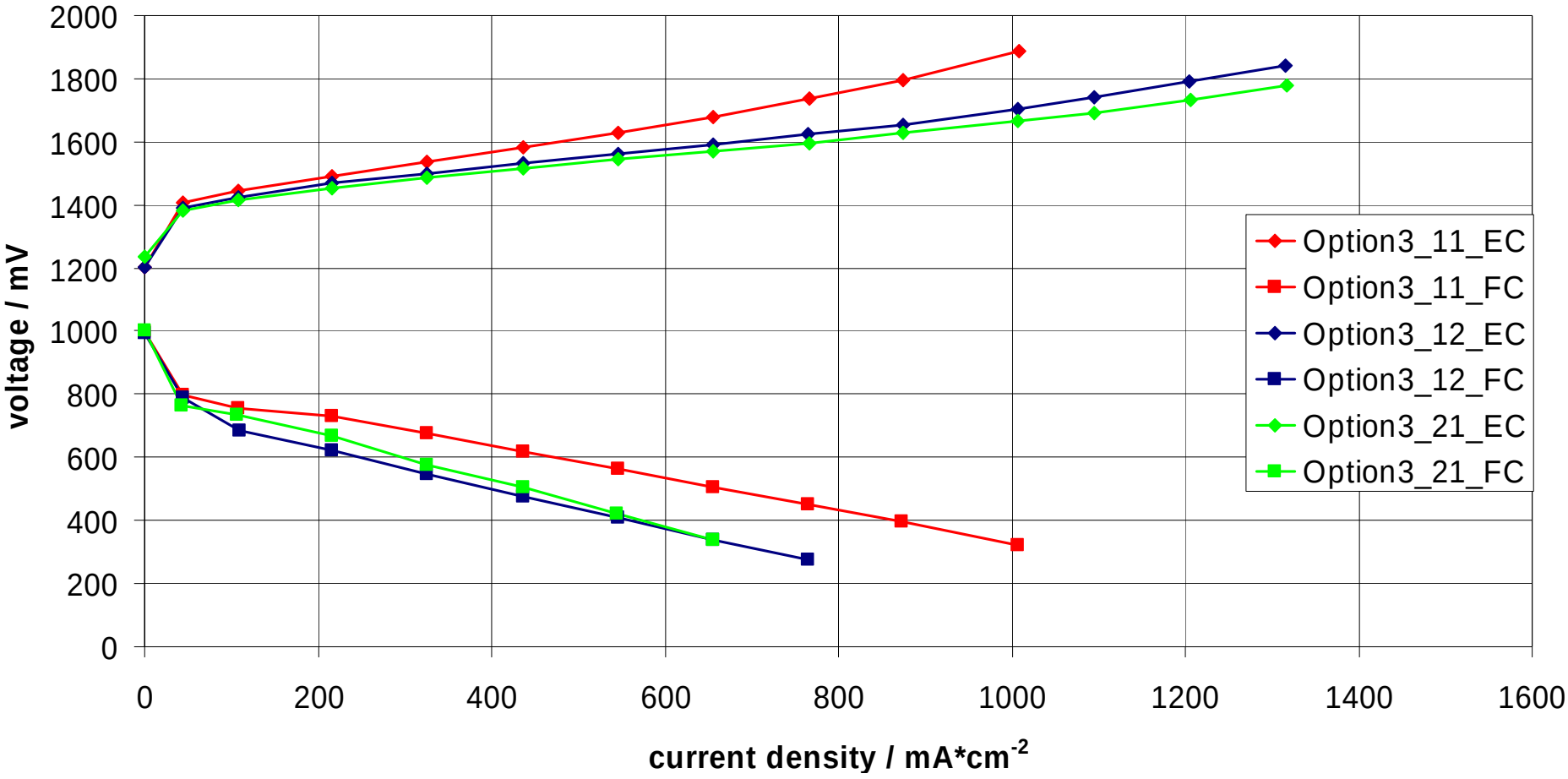
catalysts: H_2 electrode: Pt black + 30 wt% Nafion (loading ~ 0.9 mg/cm^2)

O_2 electrode: 1) IrO_2 + 30 wt% Nafion (EC) (loading ~ 0.75 mg/cm^2)

2) Pt black + 30 wt% Nafion (FC)

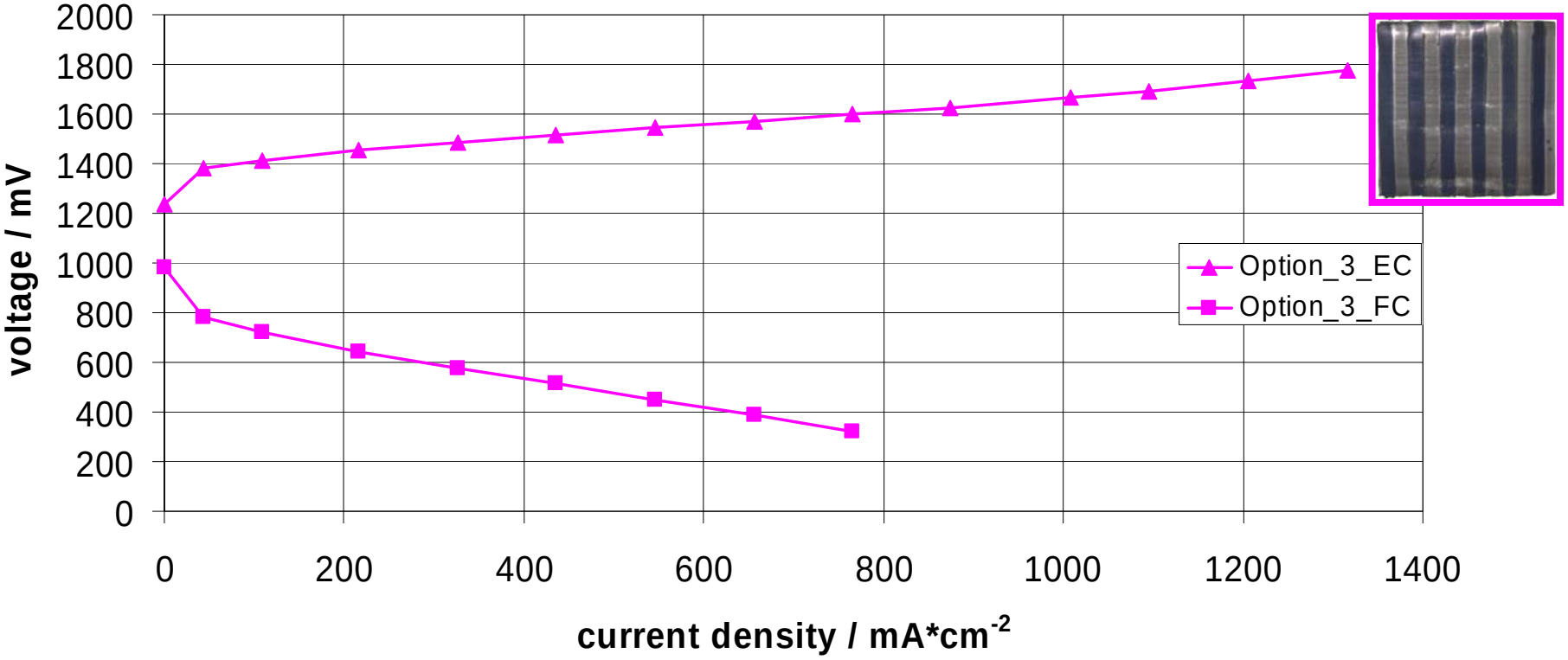
MEA Development

option 3 – segmented active area



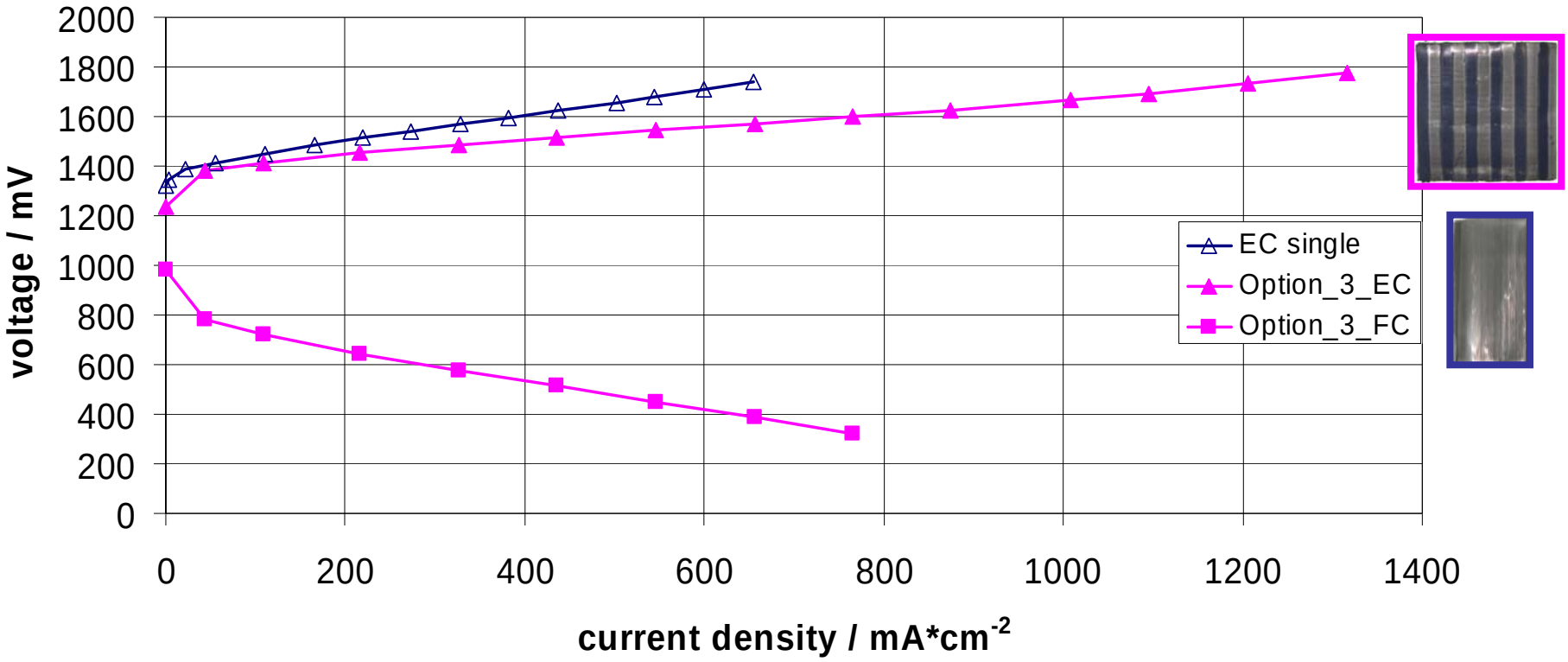
MEA Development

option 3 – segmented active area



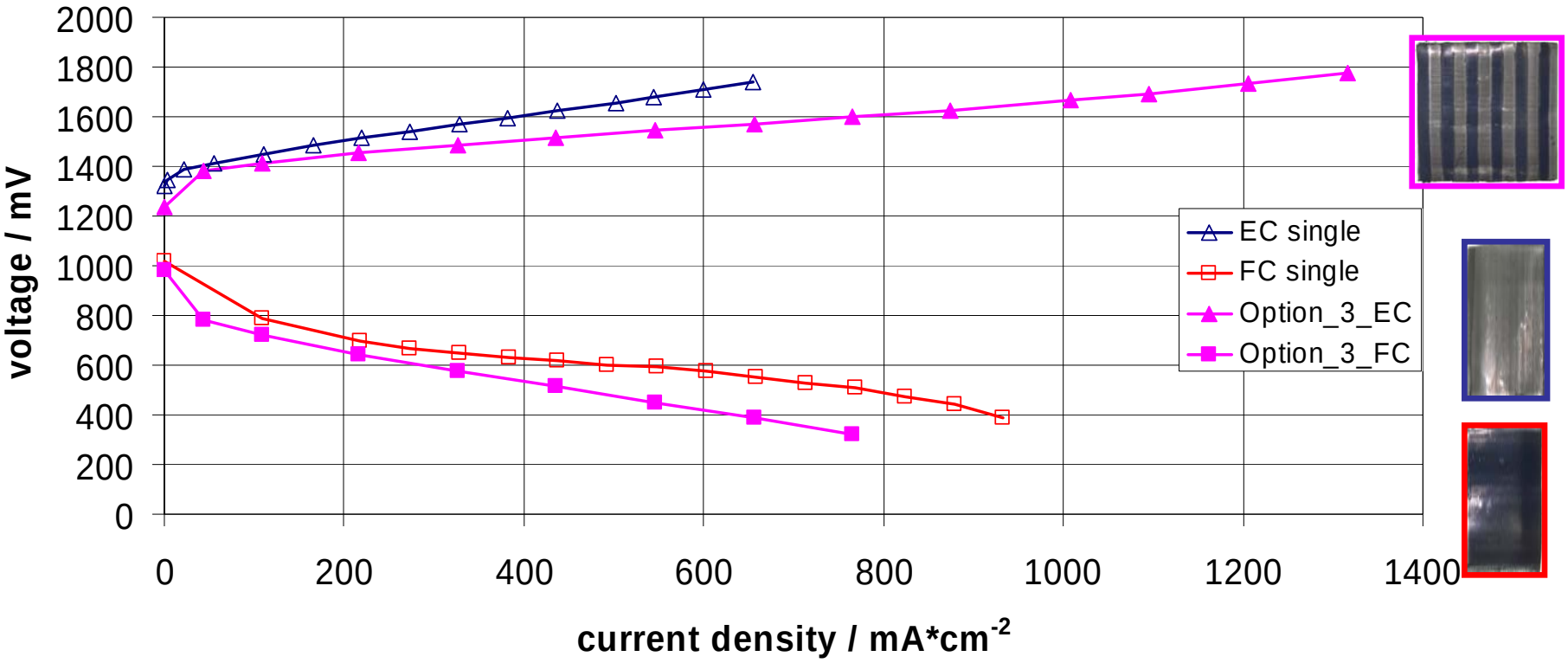
MEA Development

option 3 – segmented active area



MEA Development

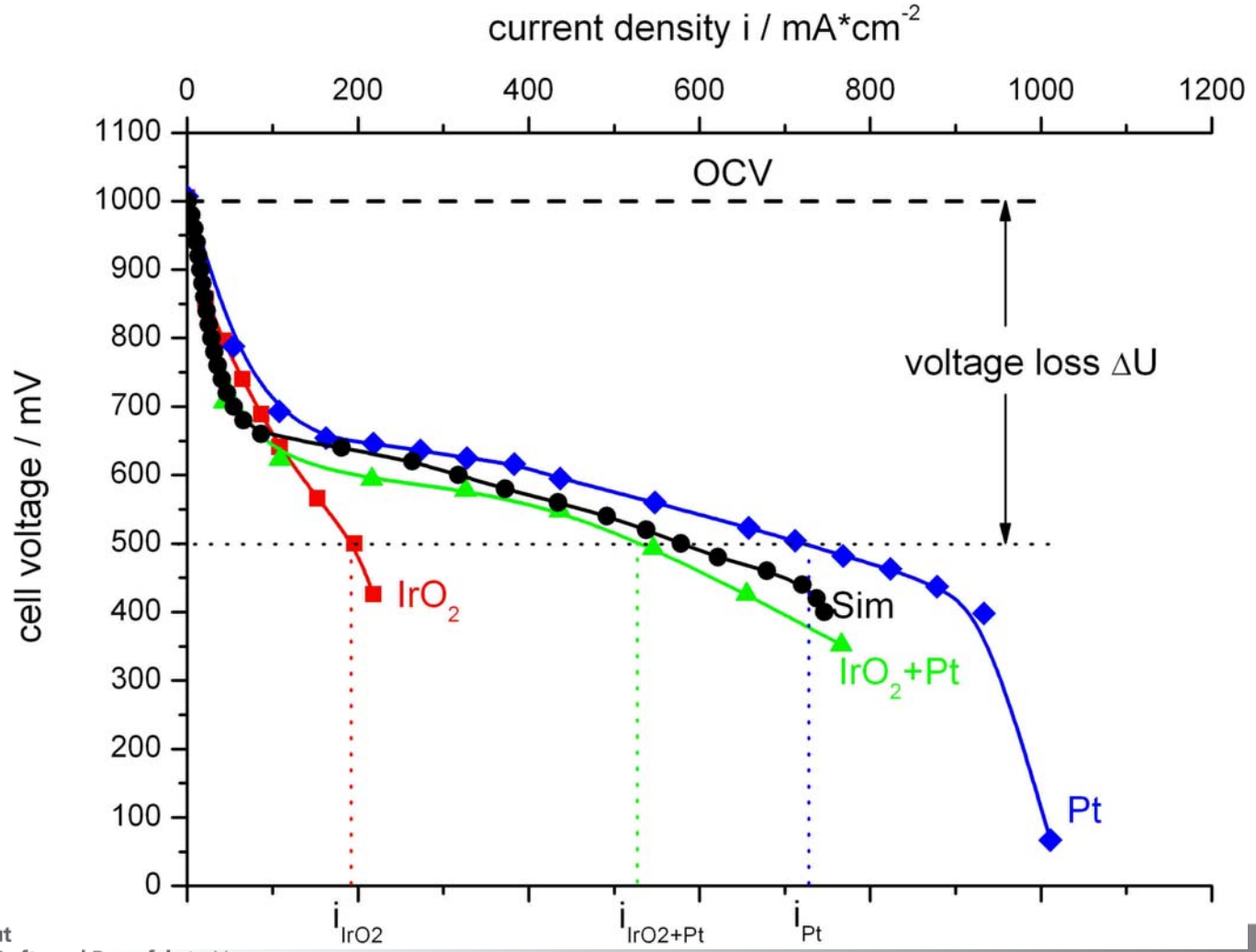
option 3 – segmented active area



- electrolysis: option3-cell better then single mode cell -> Pt reactive

MEA Development

option 3 – segmented active area



MEA Development

Summary

MEA	Fuel cell mode at 400 mA*cm^{-2}	Electrolysis mode at 1000 mA*cm^{-2}
Mixture of catalysts	700 mV	1610 mV
Multilayer electrode	680 mV	1750 mV
	525 mV	1600 mV
Segmented electrode	620 mV	1890 mV
	520 mV	1660 mV

Conclusion

- Bifunctional electrodes for use in closed-loop fuel cell applications with different configurations developed and compared
- Performance in electrolysis equal to generic electrolysis cells
- Performance in fuel cell mode at medium current density (400 mA*cm^{-2}) nearly equal to PEFC
- Round trip efficiency: ~ 48 % (at 400 mA*cm^{-2}: FC 700 mV; EC 1450 mV)

- No long-term stability (especially in electrolysis mode)
- Coal-based backings (SGL 35 DC) shows strong degradation, but no alternative material available

Thank you for your attention!

Any questions?