



Development of Bifunctional Electrodes for Closed-loop Fuel Cell Applications

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Introduction

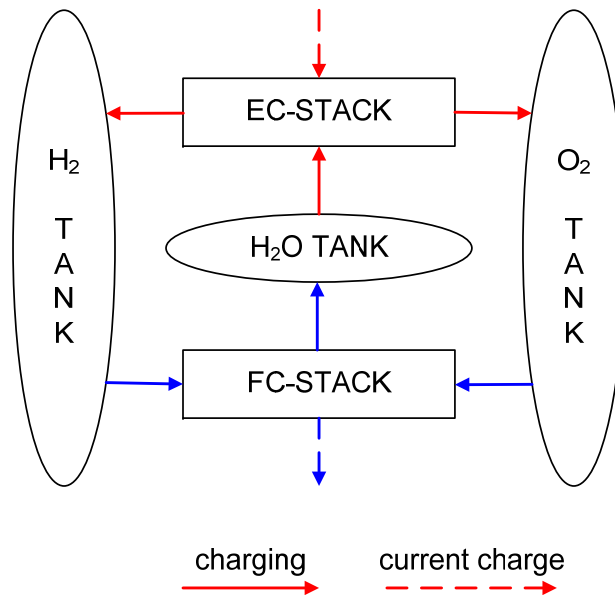
- Stand-alone systems without grid connection
 - manned (long-term) space missions
 - UAV (unmanned air vehicle)
 - local stationary energy supply

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

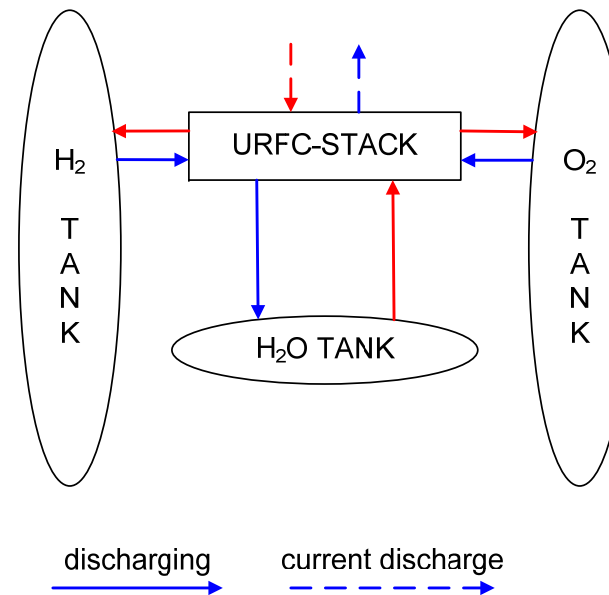


Regenerative Fuel Cell

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

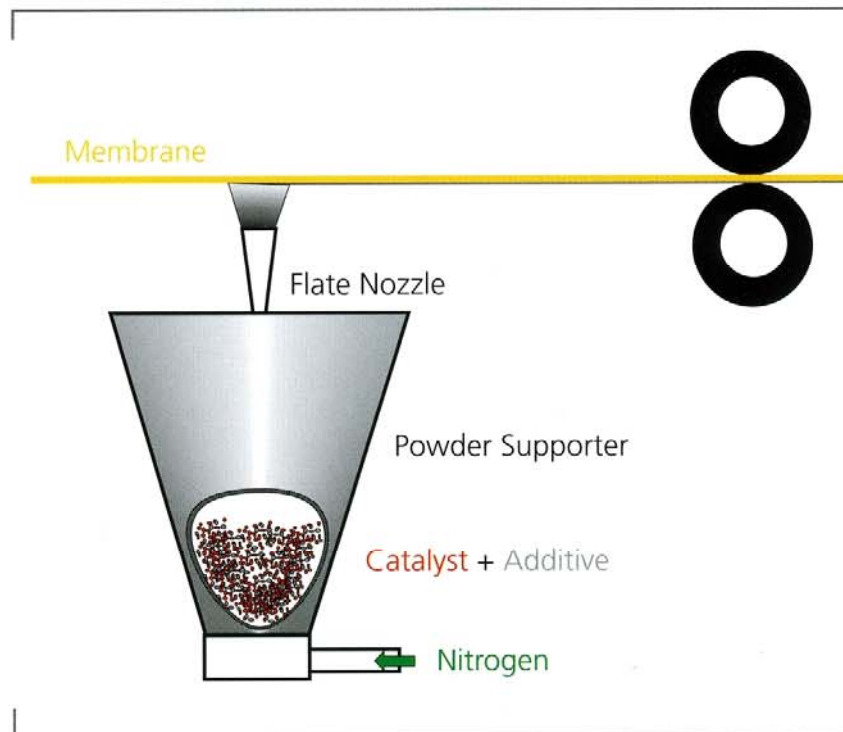


Figure 1: Principle of dry coating method for electrode production

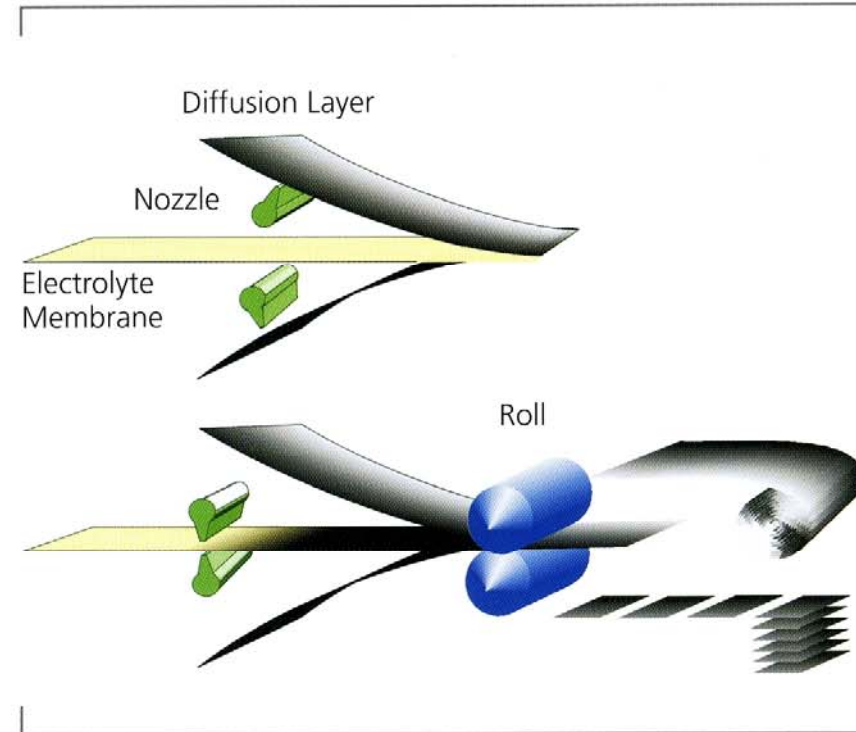


Figure 2: Production of membrane electrode assemblies by dry spray coating. Two alternative methods are shown.



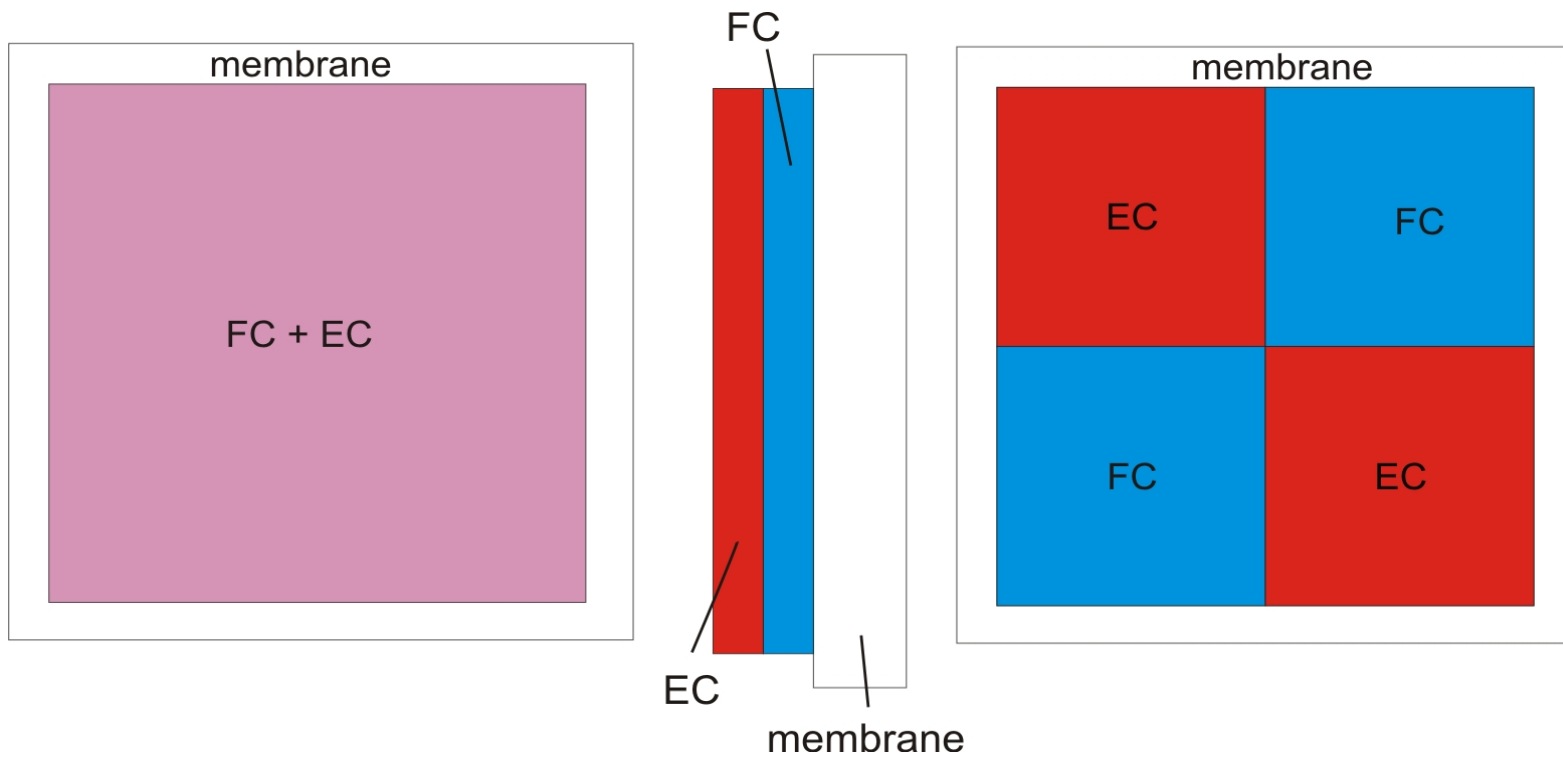
Preparation

- 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

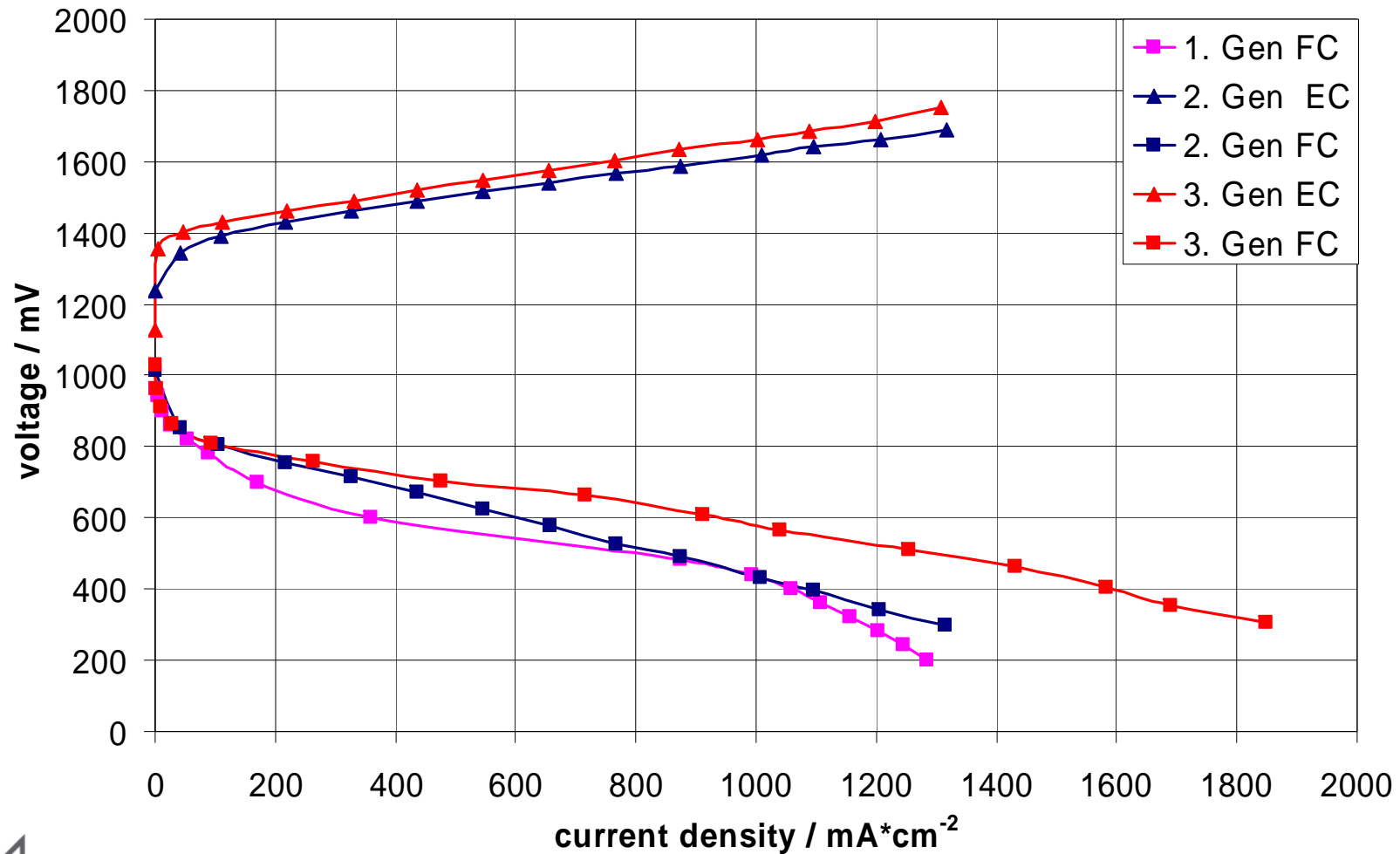
- 1st generation H₂: supported Platinum (20 wt% Pt)
 O₂: IrO₂ + Pt black (ration 1:1)
- 2nd generation H₂: Pt black
 O₂: IrO₂ + Pt black (ratio 1:1)
- 3rd generation H₂: Pt black
 O₂: IrO₂ + Pt black (ratio 3:7)

- loading H₂: ~ 0.6 to 0.8 mg/cm²
 O₂: ~ 1.5 to 1.8 mg/cm²
 30 wt% Nafion



MEA Development

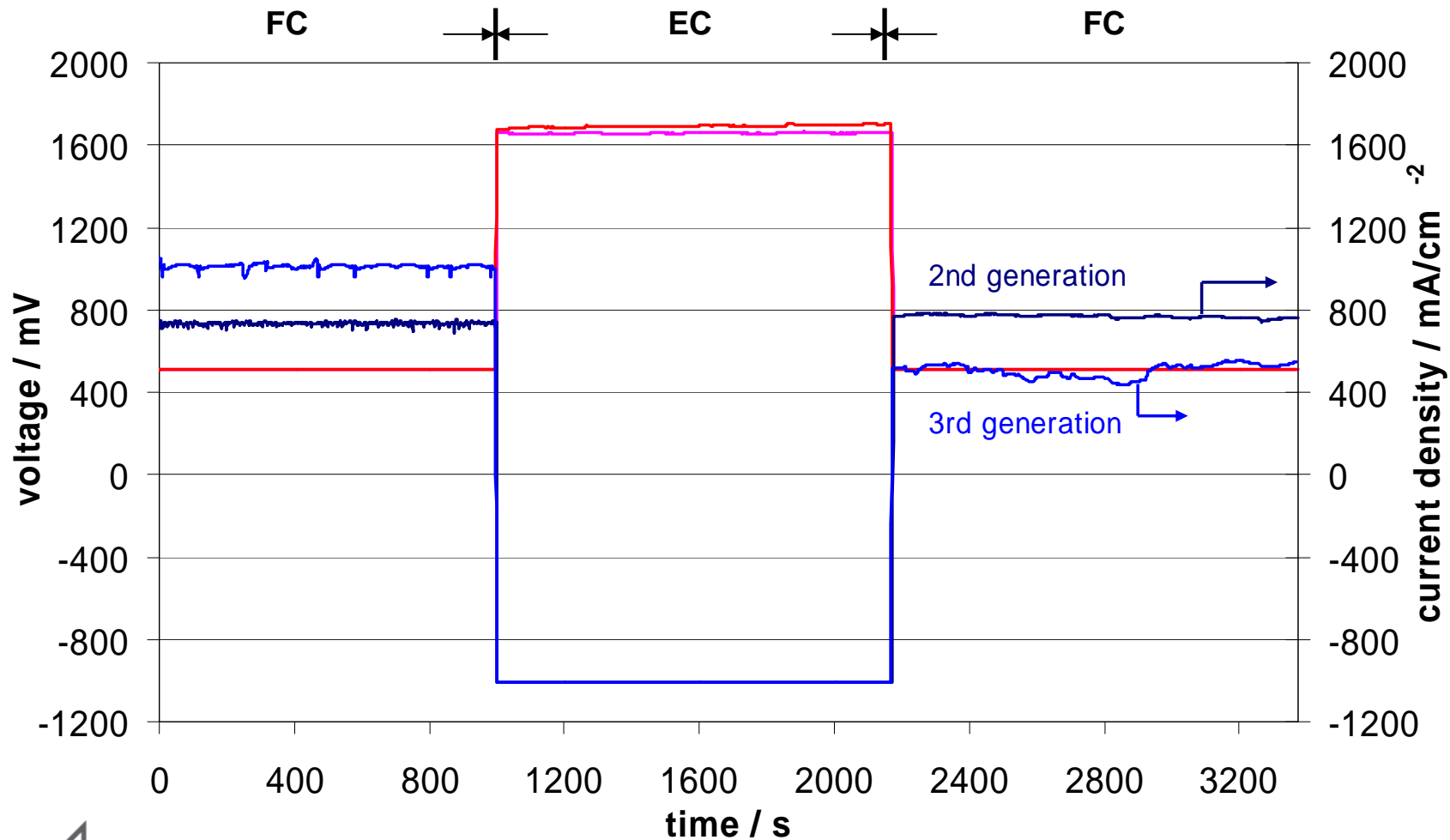
option 1 – mixture of catalysts





MEA Development

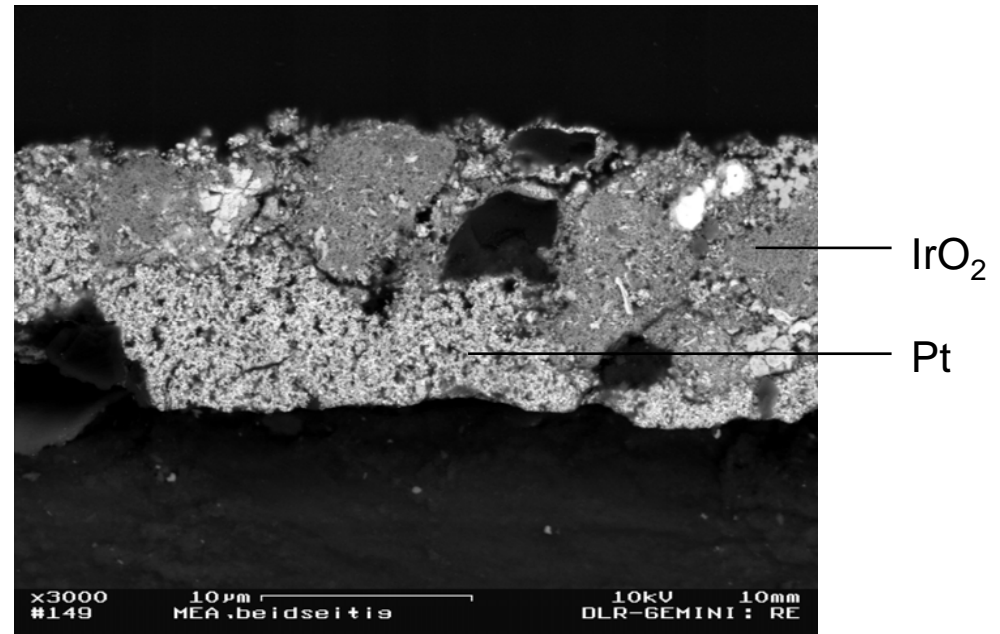
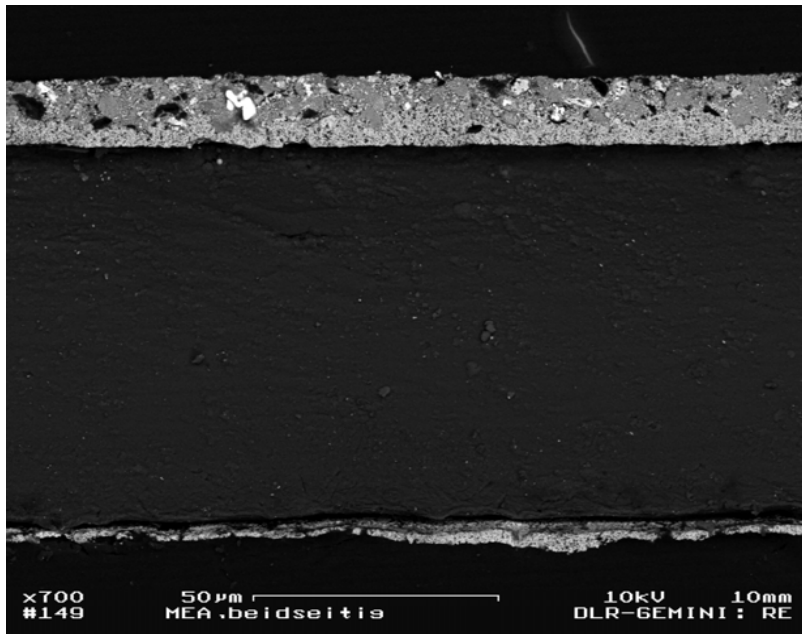
option 1 – mixture of catalysts





MEA Development

option 2 – multilayer electrode



catalysts:

H₂: Pt black + 30 wt% Nafion (loading ~ 0.7 mg/cm²)

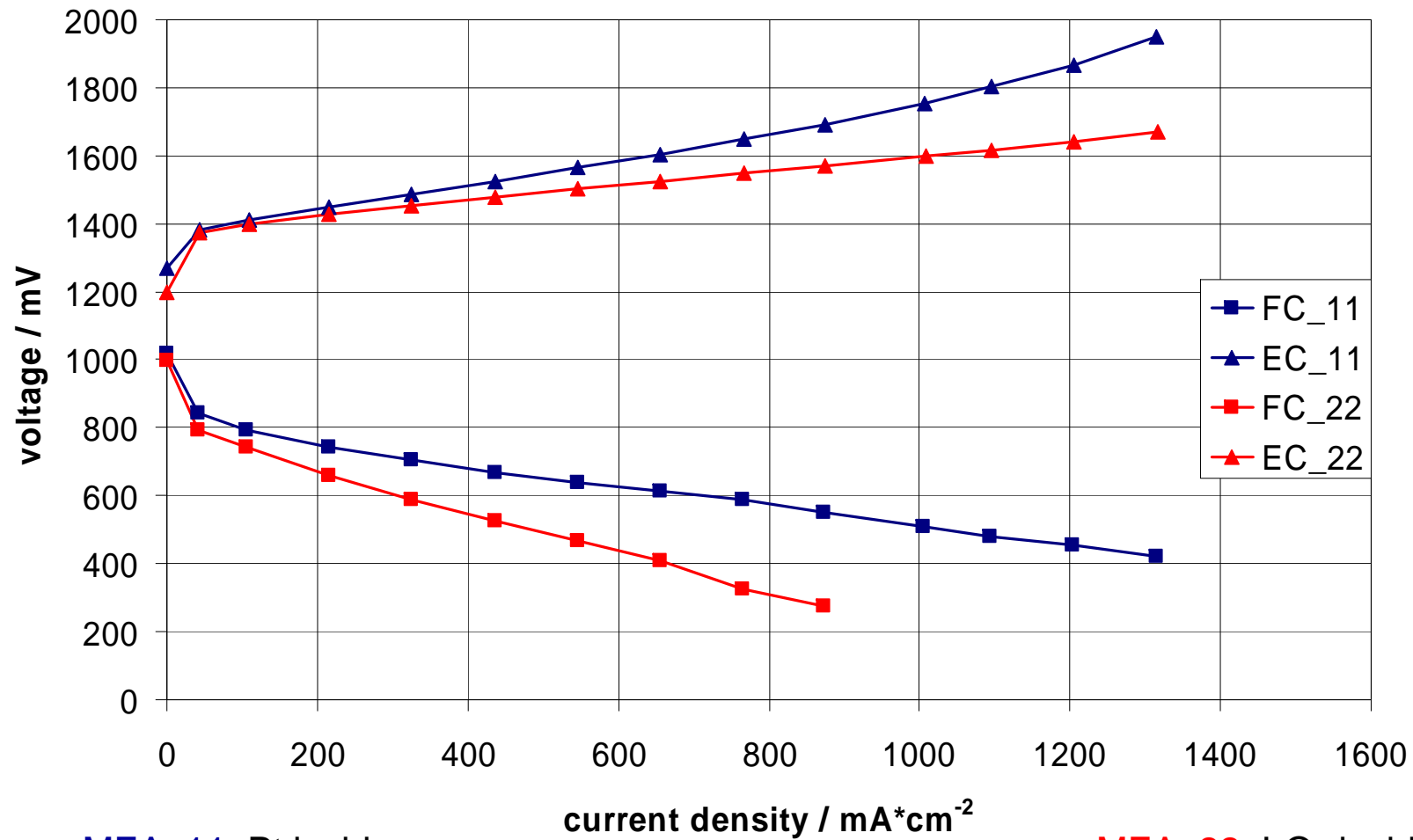
O₂: IrO₂ + 30 wt % Nafion (EC) (loading ~ 0.9 mg/cm²)

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



MEA Development

option 2 – multilayer electrode

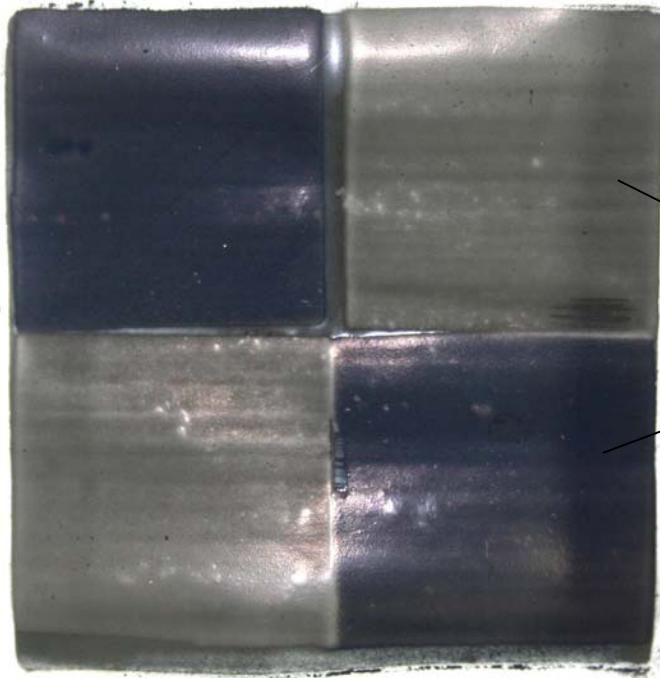




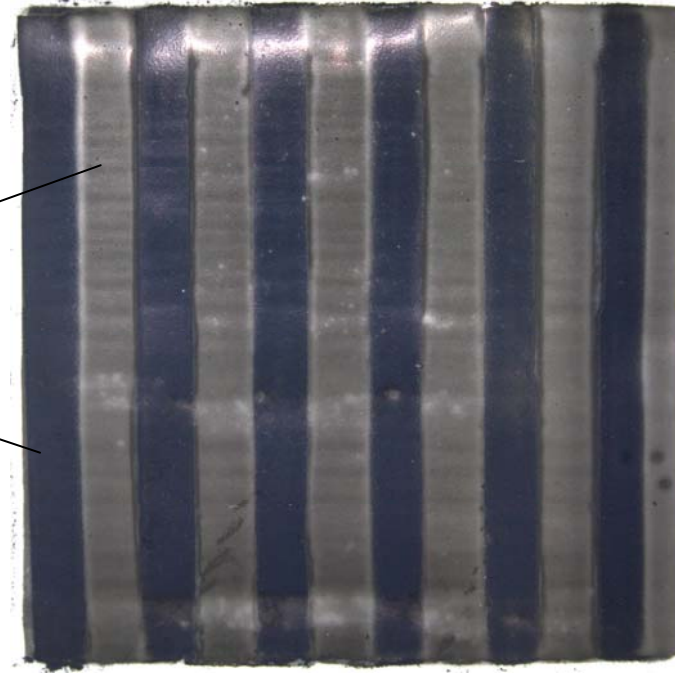
MEA Development

option 3 – segmented active area

option 3_1



option 3_2



1)

2)

catalysts: H₂ electrode:

O₂ electrode:

Pt black + 30 wt% Nafion (loading ~ 0.9 mg/cm²)

1) IrO₂ + 30 wt% Nafion (EC) (loading ~ 0.75 mg/cm²)

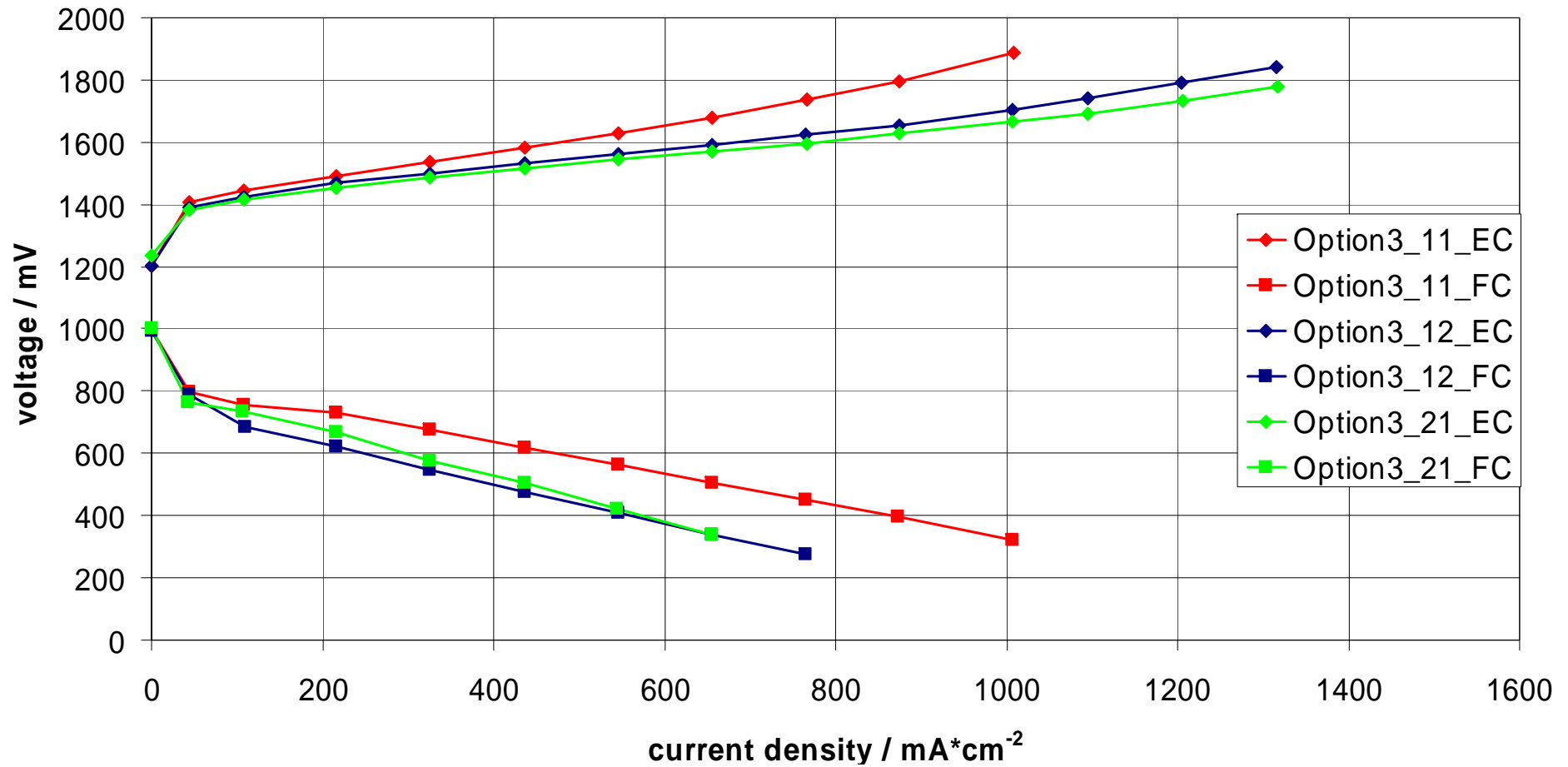
2) Pt black + 30 wt% Nafion (FC)





MEA Development

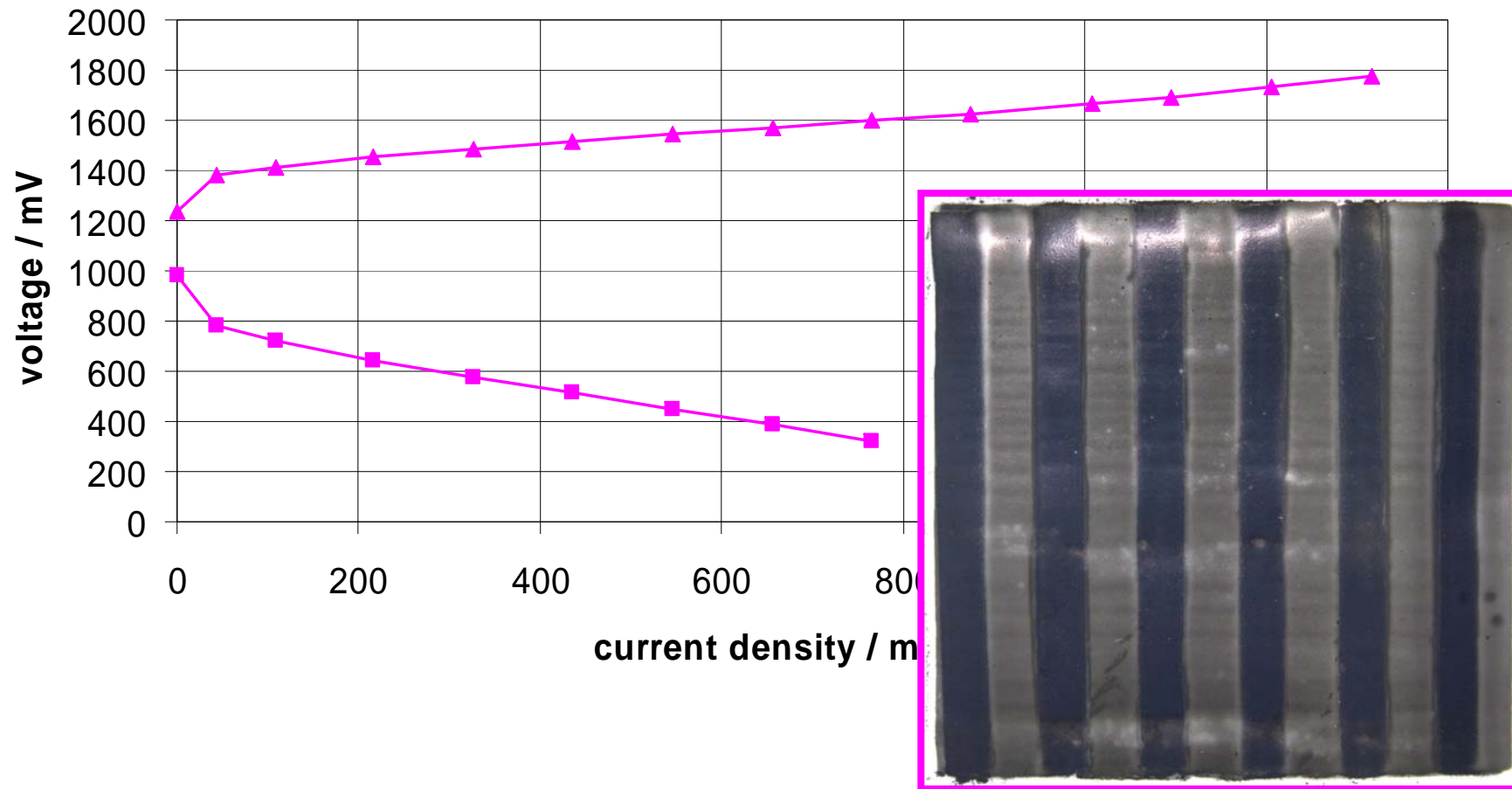
option 3 – segmented active area





MEA Development

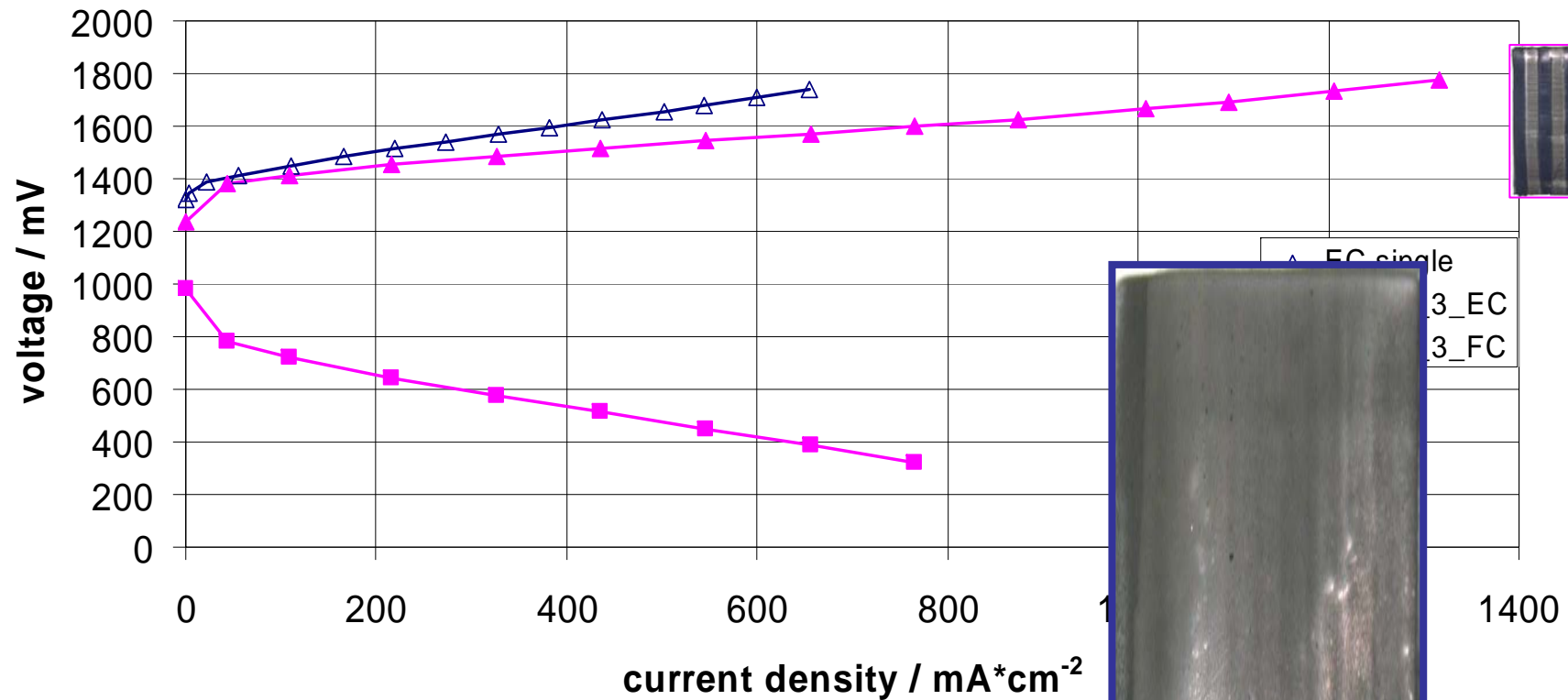
option 3 – segmented active area





MEA Development

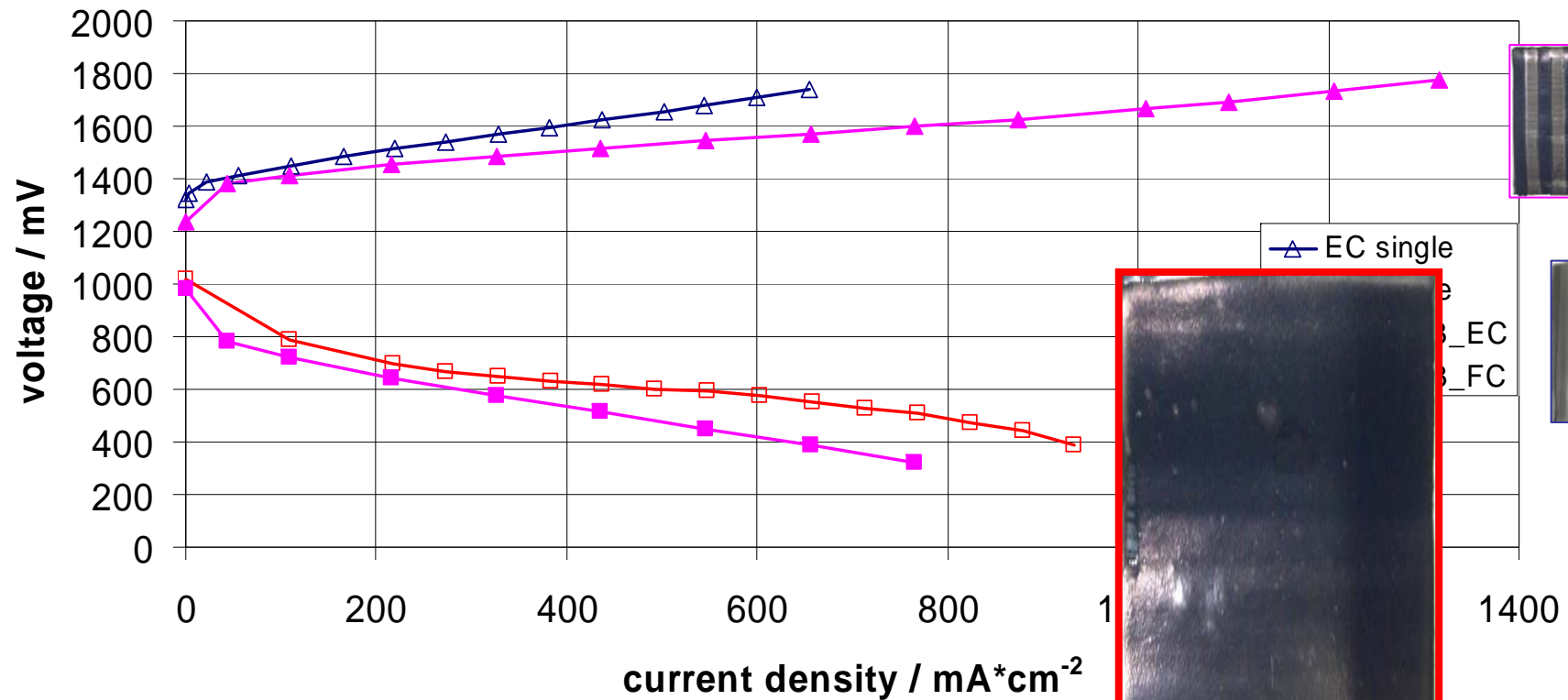
option 3 – segmented active area





MEA Development

option 3 – segmented active area



➤ electrolysis: option3-cell better than single mode active



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 ($400 \text{ mA} \cdot \text{cm}^{-2}$) nearly equal to PEFC
- Round trip efficiency: $\sim 48 \%$ (at $400 \text{ mA} \cdot \text{cm}^{-2}$: 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?