Development of mid temperature PEM membranes, catalysts and MEAs in the frame of the MT-PEMFC-Cluster project

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1: FEM, 2: DFI, 3: ZSW, 4: ICVT, 5: FILK, 6: UDE, 7: IPF, 8: ZBT, 9: HIAT, 10: IUTA, 11: MPI-K

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MT PEMFC Cluster Targets

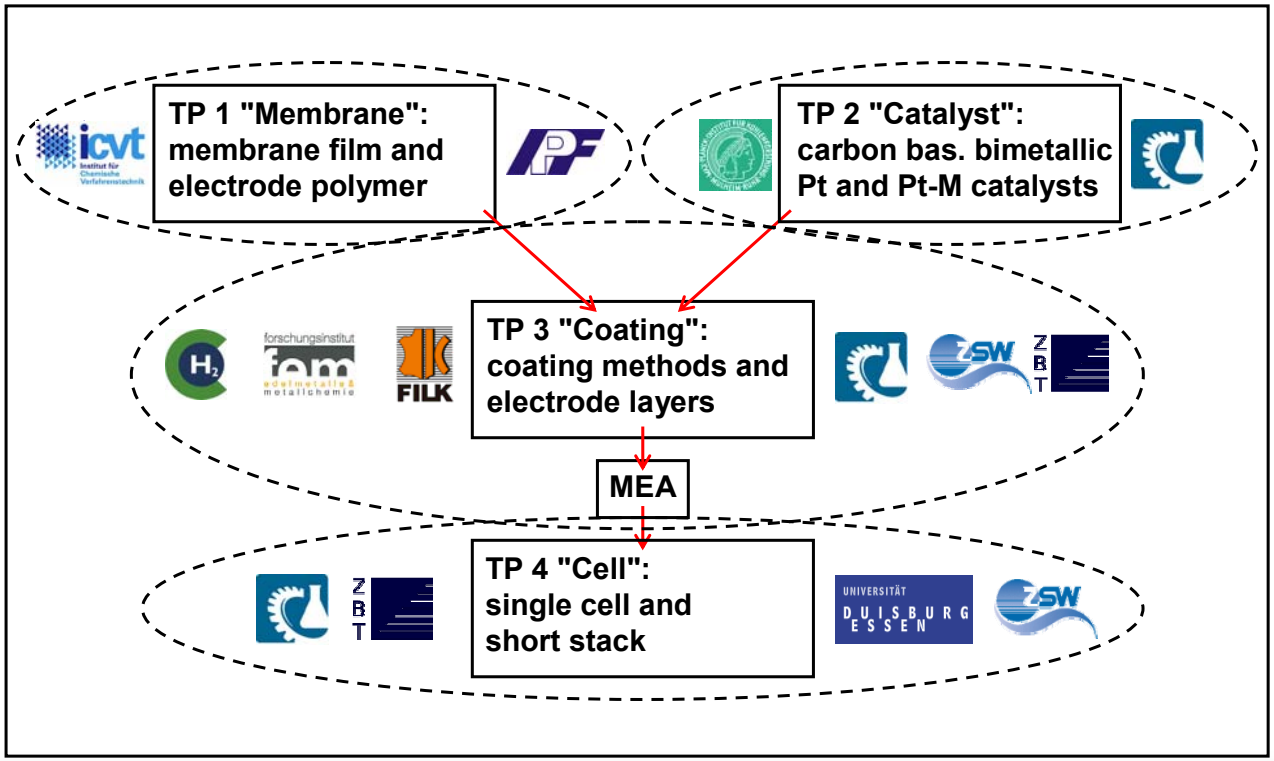
- Develop and qualify a new generation of MT (mid temperature) PEM fuel cell components for 2 applications for the temperature range of 100 - 150°C

Subprojects

- TP1: "Membrane"
- TP2: "Catalyst"
- TP3: "Coating"
- TP4: "Cell"

Applications

- DMFC (MeOH/Air)
- PEMFC (H_2/Air)



Partners and Funding

Project Partners

- 10 research institutions
- administrative support by IUTA

Funding Institutions

- DFG (Deutsche Forschungs-gemeinschaft): TP1 + TP2
- AIF (Allianz Industrie Forschung): TP3 + TP4

ALLIANZ INDUSTRIE FORSCHUNG

Deutsche Forschungsgemeinschaft

DFG

iuta

DECHEMA-Forschungsinstitut Frankfurt am Main DFI	
Forschungsinstitut für Edelmetalle und Metallchemie Schwäbisch Gmünd FEM	
Forschungsinstitut für Leder und Kunststoffbahnen Freiberg FILK	
Hydrogen Institute of Applied Technologies Schwerin HIAT	
Institut für Chemische Verfahrenstechnik Universität Stuttgart ICVT	
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Max-Planck-Institut für Kohlenforschung Mülheim an der Ruhr MPI-K	
Energietechnik, Universität Duisburg-Essen Duisburg UDE	
Zentrum für BrennstoffzellenTechnik GmbH Duisburg ZBT	
Zentrum für Sonnenenergie- u. Wasserstoff-Forschung Ulm ZSW	

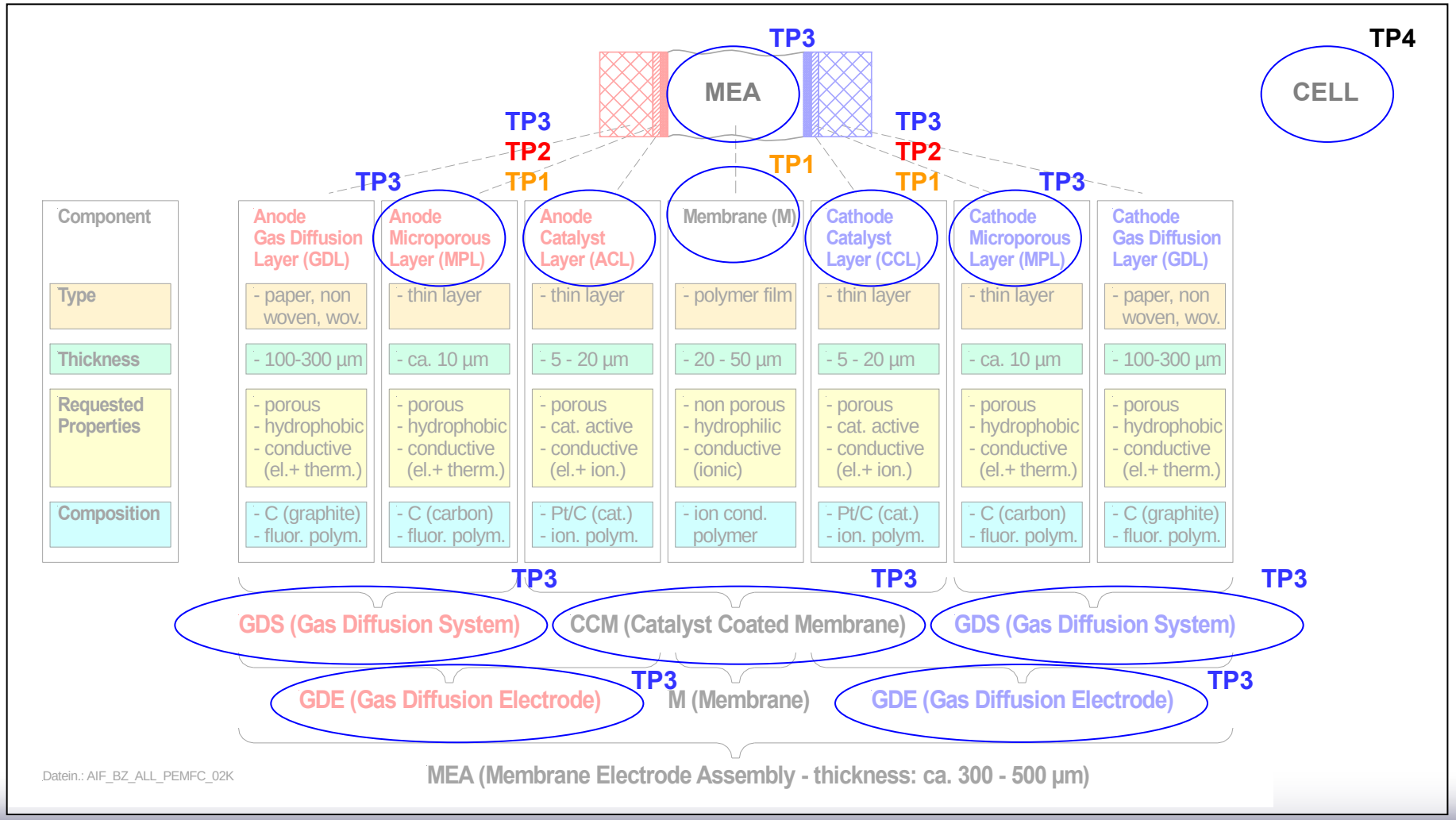
Development Strategy

- Develop and qualify materials, hardware and processes
  first for LT (80°C), than for MT (100 - 150°C) applications
  - raw materials (polymers, catalysts)
  - coatings, composites (GDS, GDE, CCM, MEA)
  - test cells (test hardware)
  - test and qualification protocols (MEA testing procedures)

- Raw material and composite development focused on
  - suitability, compatibility
  - high performance
  - good reproducability
  - high lifetime

Subprojects and Components Developed

TP1: Membrane (Polymer)
TP2: Catalyst
TP3: Coating (Composites)
TP4: Cell



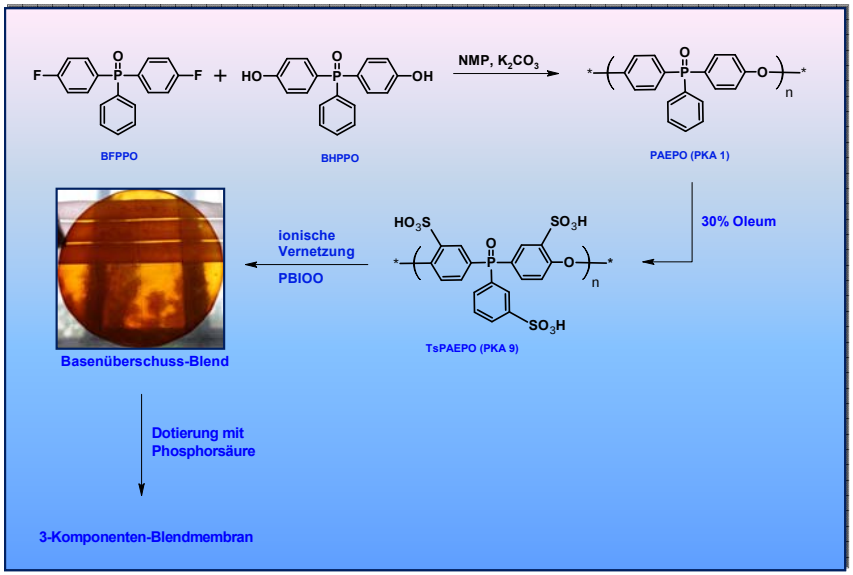
4-Column Concept and Most Promising Composite Types

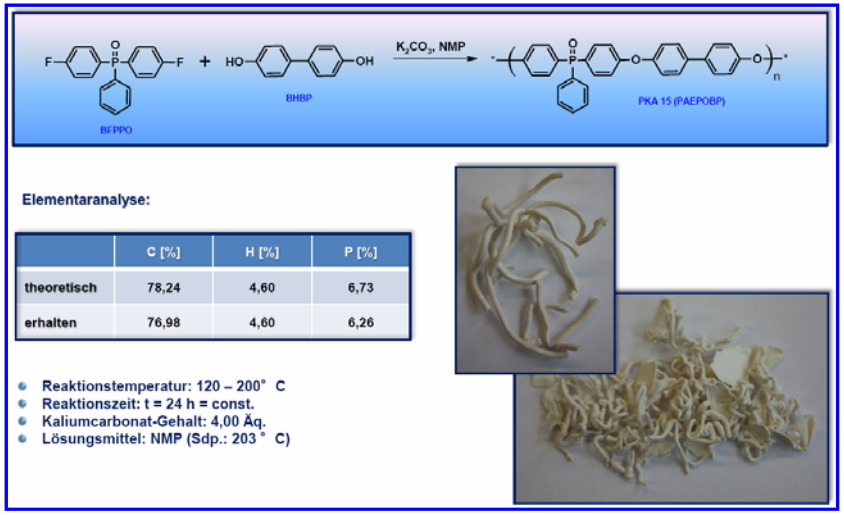
Column 1	Column 2	Column 3	Column 4
phosphonic acid polymeric composites MT PEMFC	acid-excess acid-base composites MT DMFC	H_3PO_4-doped base-excess base-acid composites MT, HT PEMFC	polymer ionic liquid composites MT PEMFC

Column 1	Column 2	Column 3	Column 4
blended membrane, phosphonated poly(pentafluor-styrol) and F6-PBI	blended membrane, sPSU and PBIOO	phosphonated poly(pentafluor-styrol) and PBIOO H_3PO_4-doped sPSU and PBIOO	tbd.

Promising Polymers (PAEPO/PATEPO g/h/i + PWN2010)

g	h
i	PWN

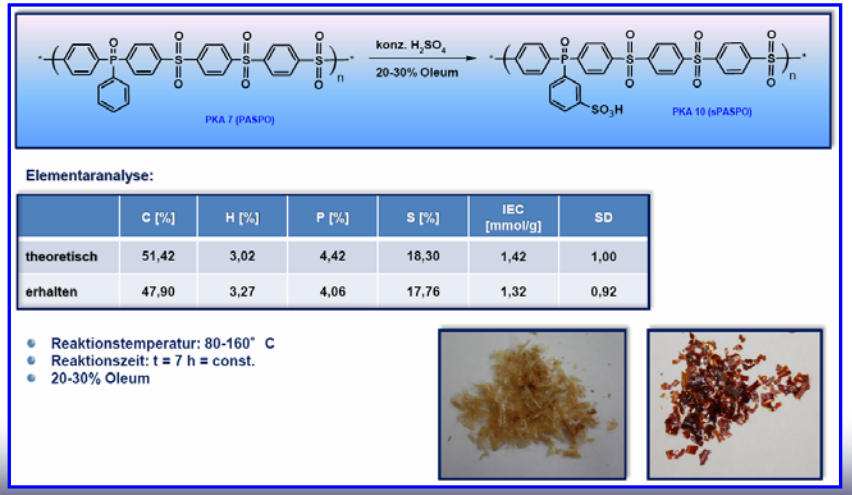




Elementaranalyse:

	C [%]	H [%]	P [%]
theoretisch	78,24	4,60	6,73
erhalten	76,98	4,60	6,26

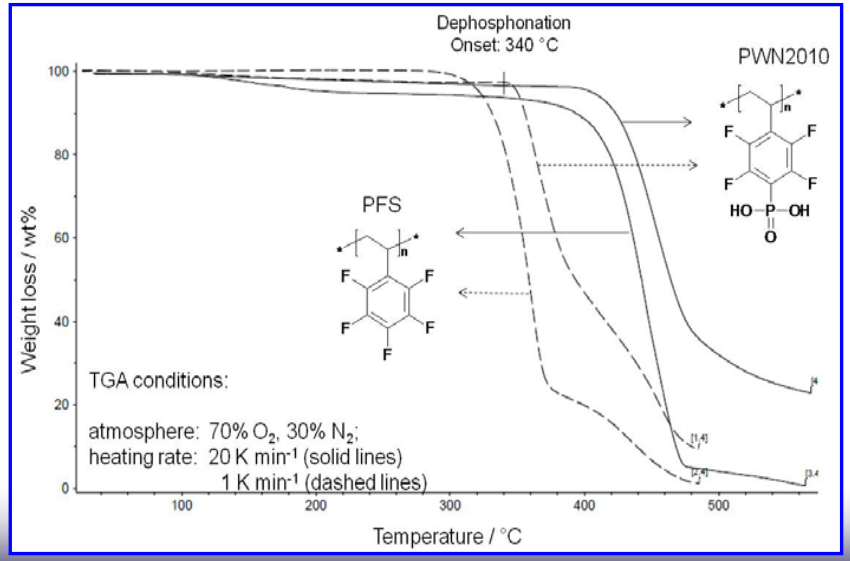
- Reaktionstemperatur: 120 – 200° C
- Reaktionszeit: t = 24 h = const.
- Kaliumcarbonat-Gehalt: 4,00 Äq.
- Lösungsmittel: NMP (Sdp.: 203 ° C)



Elementaranalyse:

	C [%]	H [%]	P [%]	S [%]	IEC [mmol/g]	SD
theoretisch	51,42	3,02	4,42	18,30	1,42	1,00
erhalten	47,90	3,27	4,06	17,76	1,32	0,92

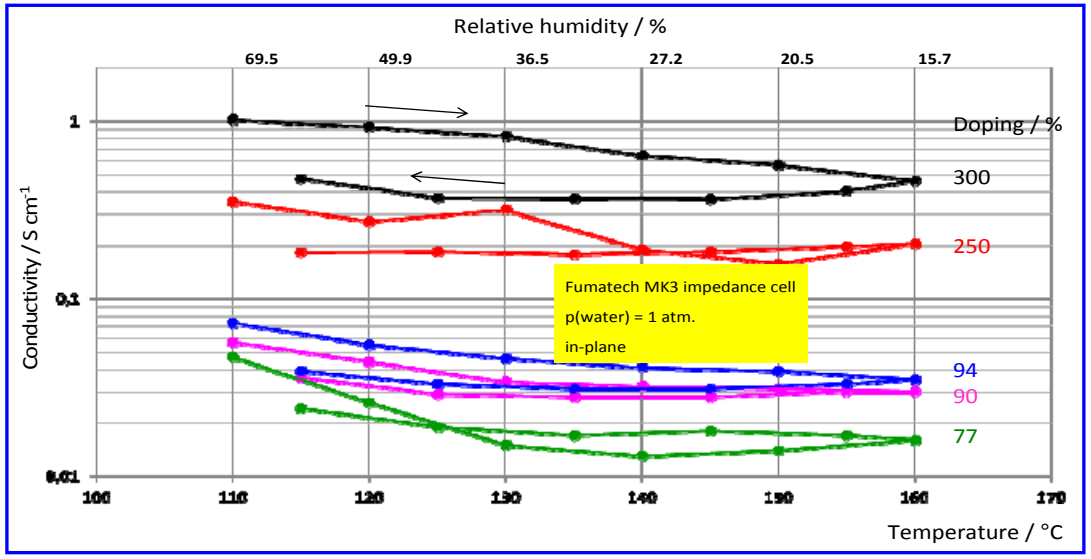
- Reaktionstemperatur: 80-160° C
- Reaktionszeit: t = 7 h = const.
- 20-30% Oleum

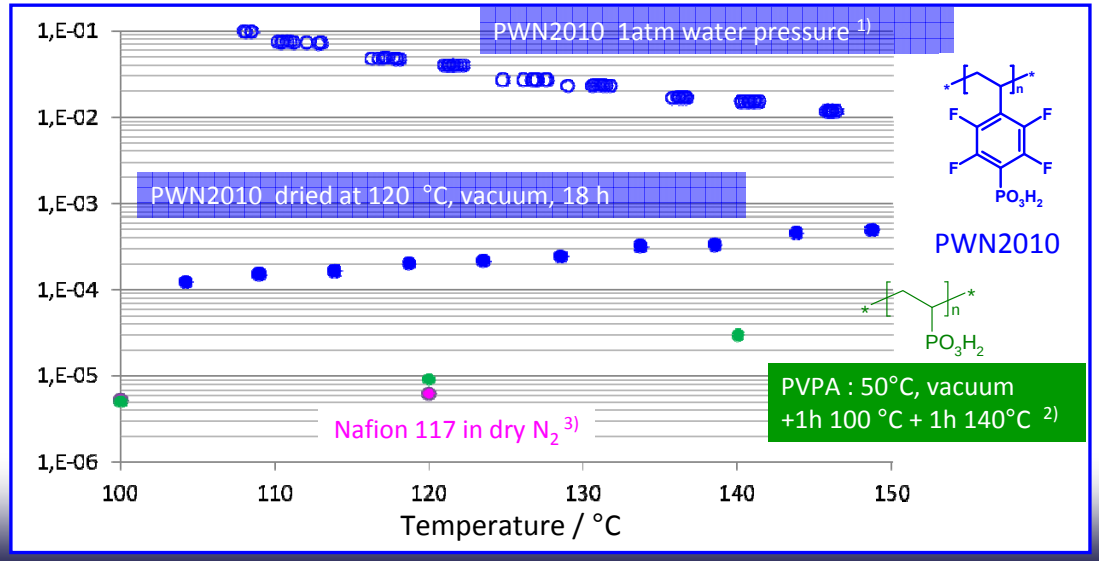


H⁺ Conductivity of Polymers

H_3PO_4 doped PWN2010/PBIOO

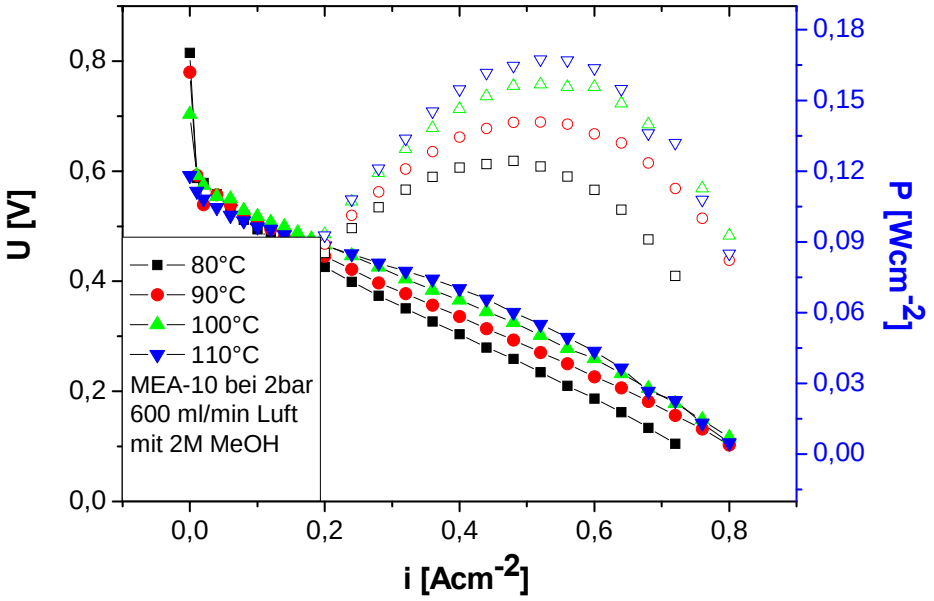
PWN 2010



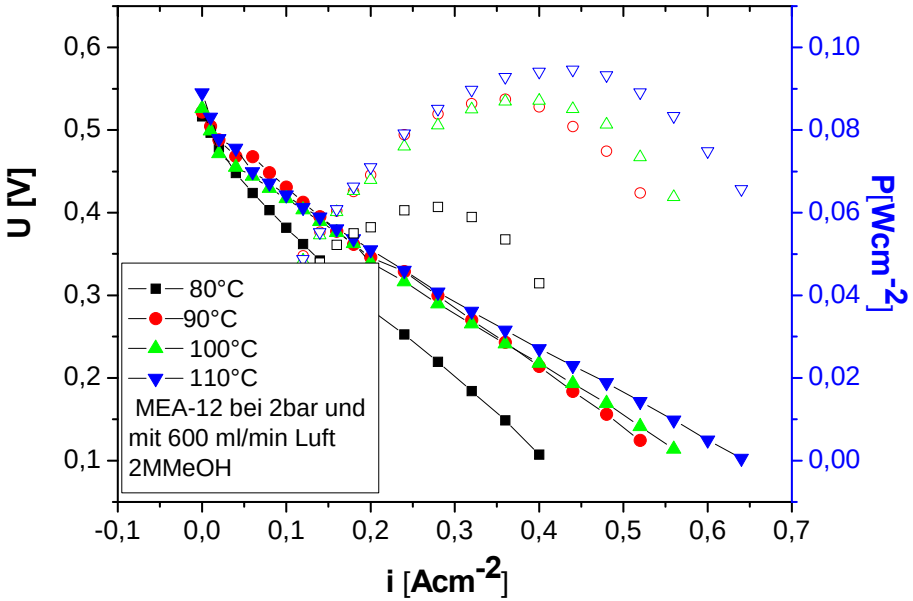


DMFC Performance: SFS001-PBIF6 (col. 2)

- Anode: 2 mg cm^{-2} (35wt%) **Pt-Ru/V** on **TGP-H -60**
- Cathode: **3,3 mg_{Pt} cm^{-2}** (30wt%) **Pt/Vulcan** on **F.CX190**
- Membrane: **Nafion 117** or **Polymer Nr. 3** (SFS001-PBIF6--Nr.3) with 13,5% PBI
- Conditions: 2M MeOH, 80-110°C, 2 bar, air

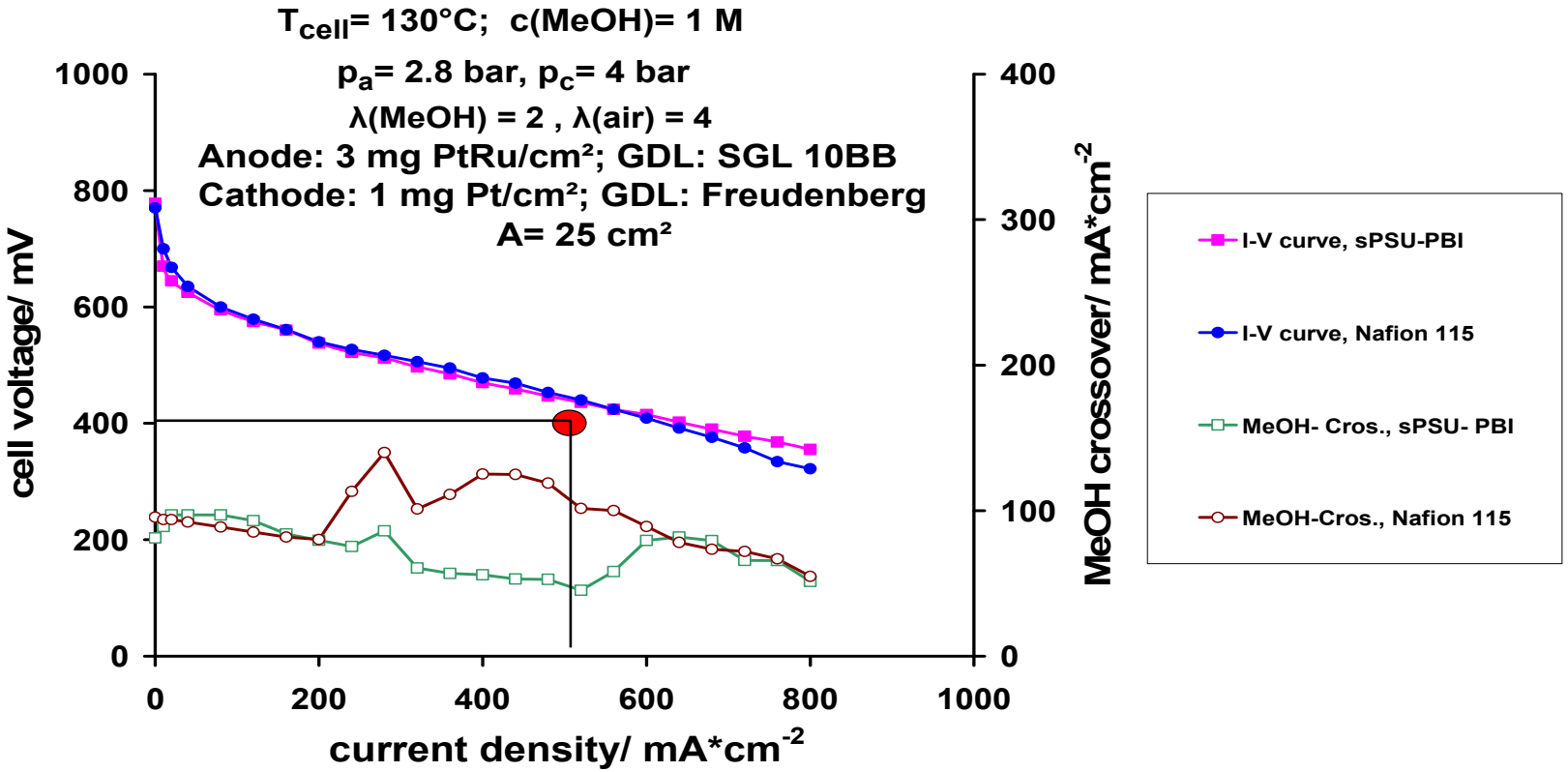


Nafion 117

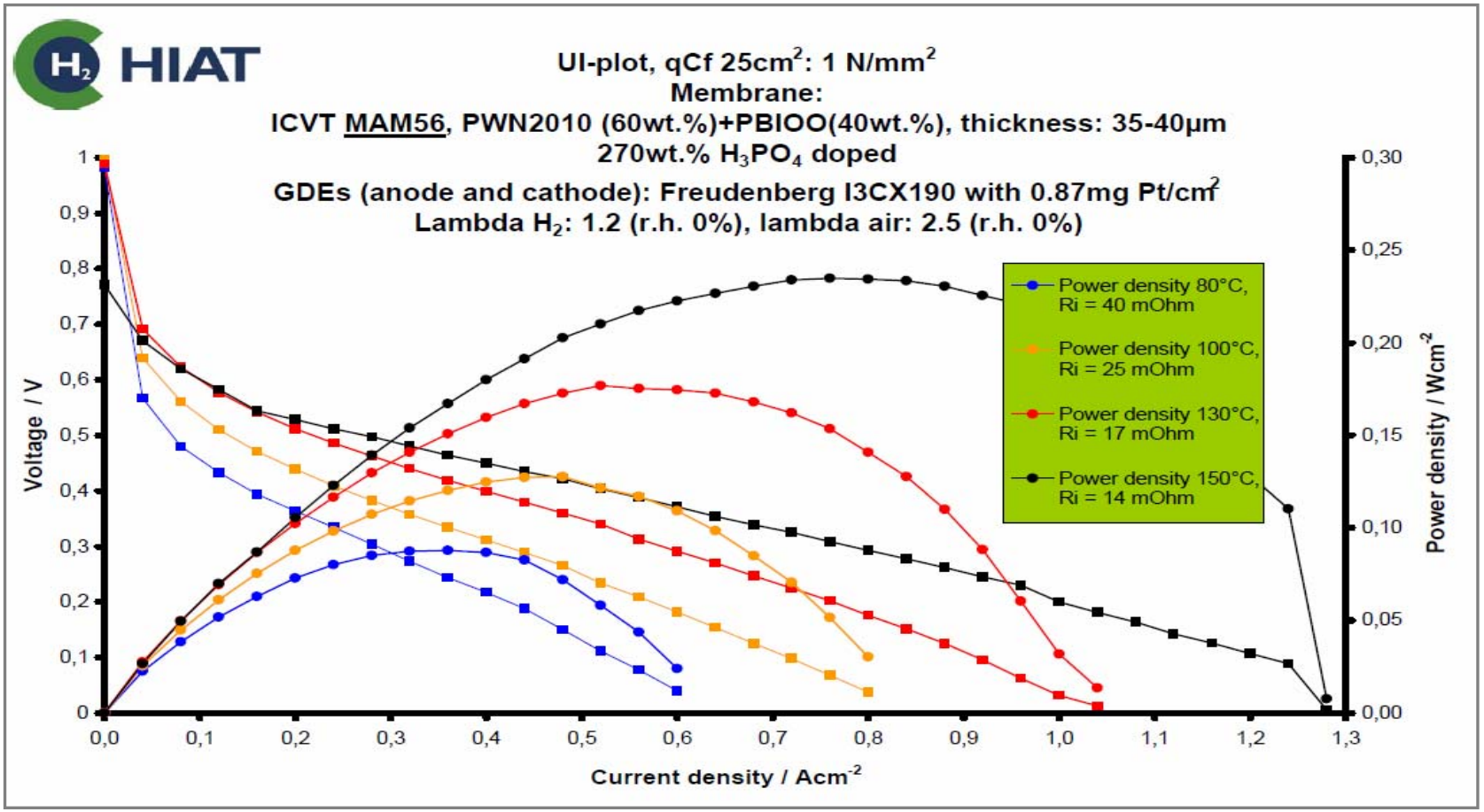


Polymer Nr. 3 (SFS001-PBIF6-Nr.3)

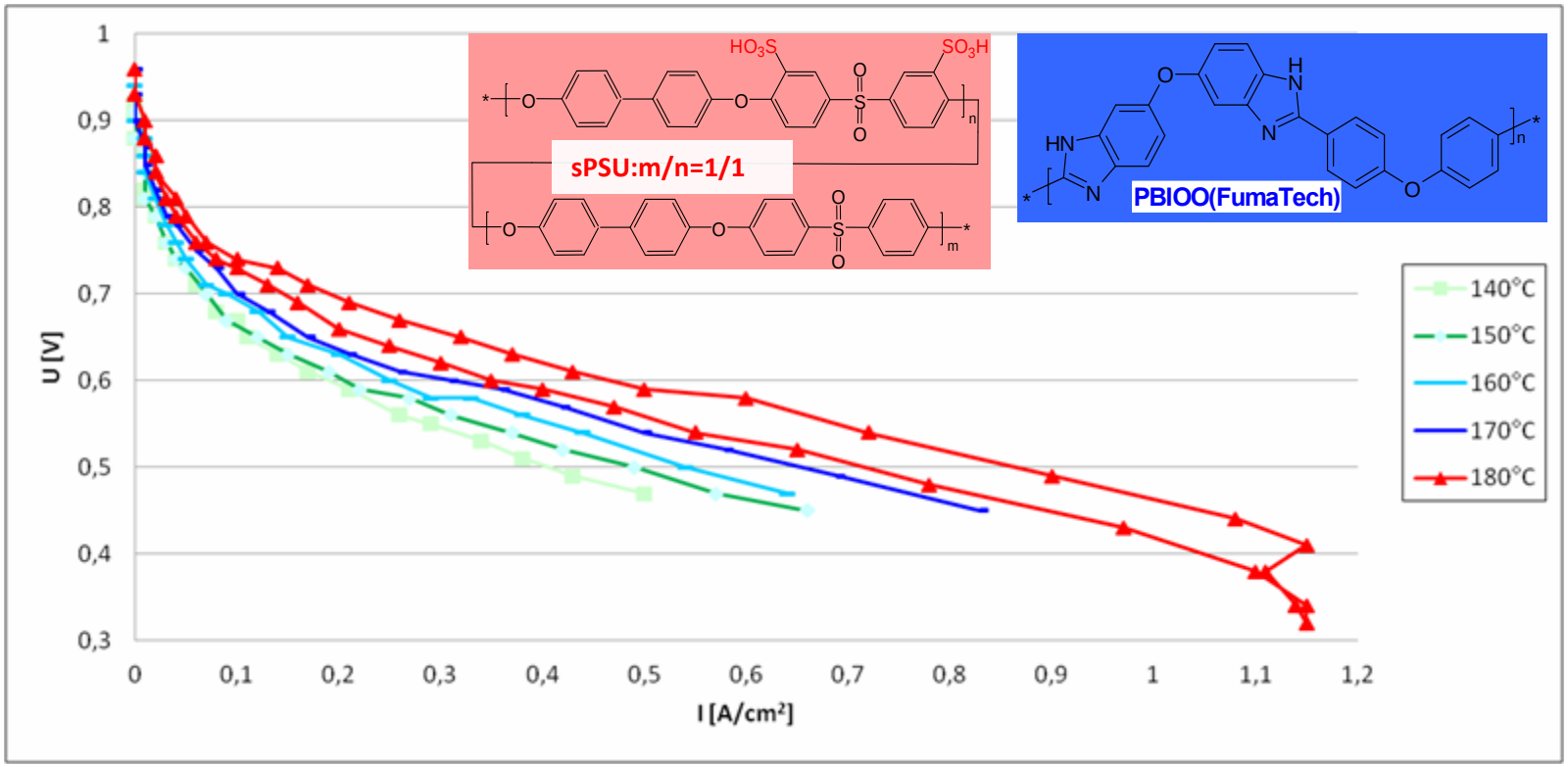
DMFC Performance: sPSU-PBI membrane (col. 2)



PEMFC Performance: PWN2010-PBIOO, H_3PO_4 doped (col. 3)

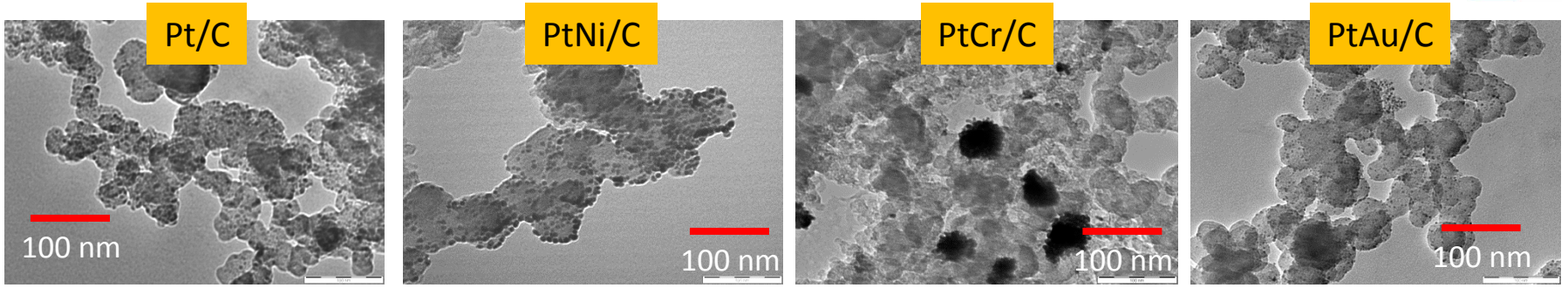


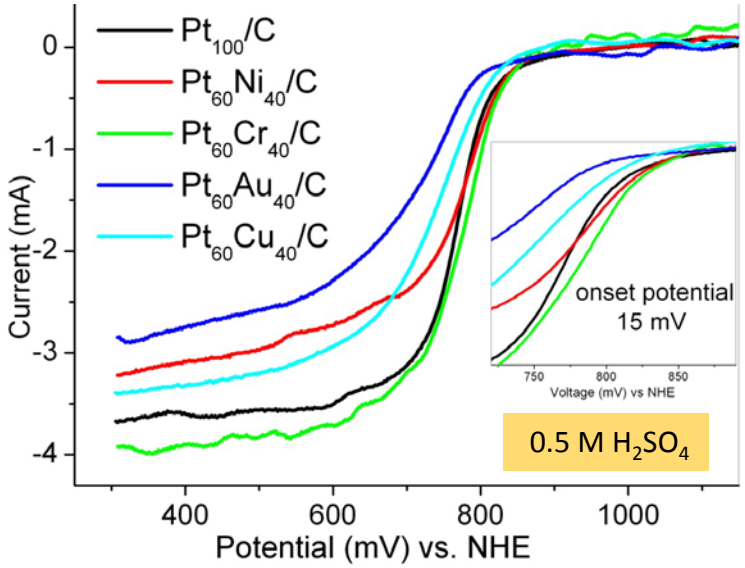
PEMFC Performance: H_3PO_4-Doped sPSU-PBIOO Acid-Base Blend (HT-PEM 140 - 180°C Hydrogen/Air)

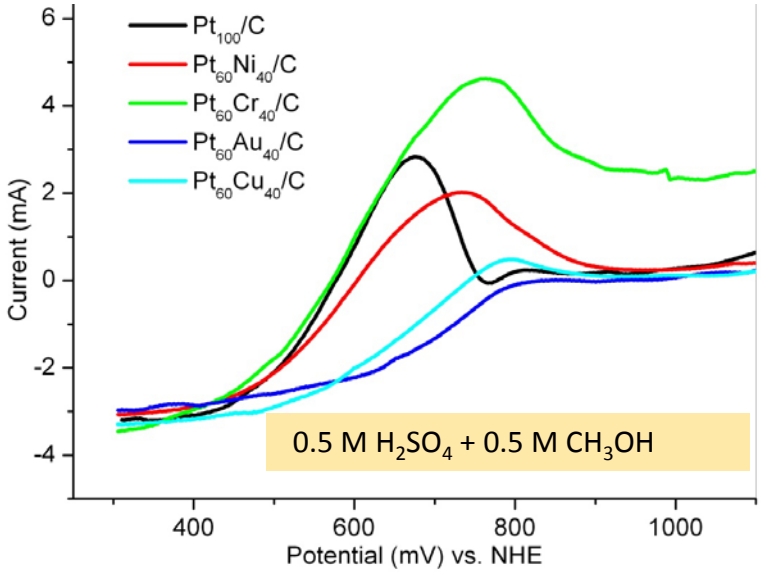


H_3PO_4-doping degree: 280%
active area 25 cm², gases: H_2, air 1bar (absolute), lambda: 1.5
rel. humidity: 0% (operation with dry gases)
Standard GDE (JM); anode: 2,5 mg PtRu/cm², cathode: 3 mg Pt/cm²

Pt-M alloys on Vulcan substrate (ORR, ORR + MeOH)

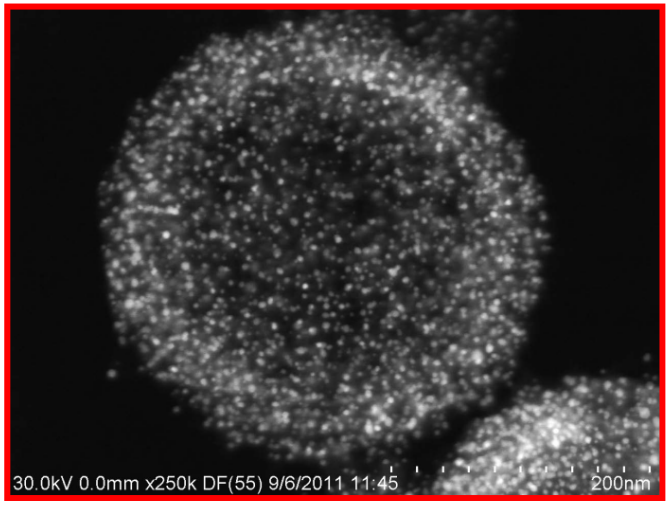




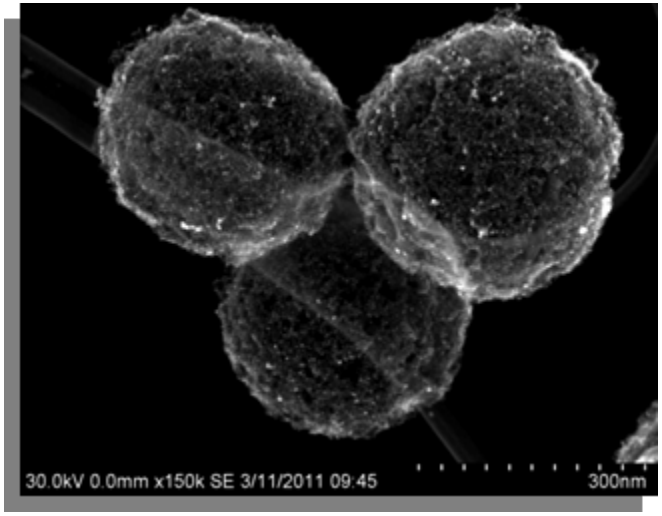


- Particle size in the range of 3-7 nm for Pt, PtNi & PtAu and 30-50 nm for PtCr
- ~15 mV less overpotential for ORR observed at $Pt_{60}Cr_{40}/C$ compared to Pt/C
- Highest methanol tolerance during ORR for $Pt_{60}Au_{40}/C$

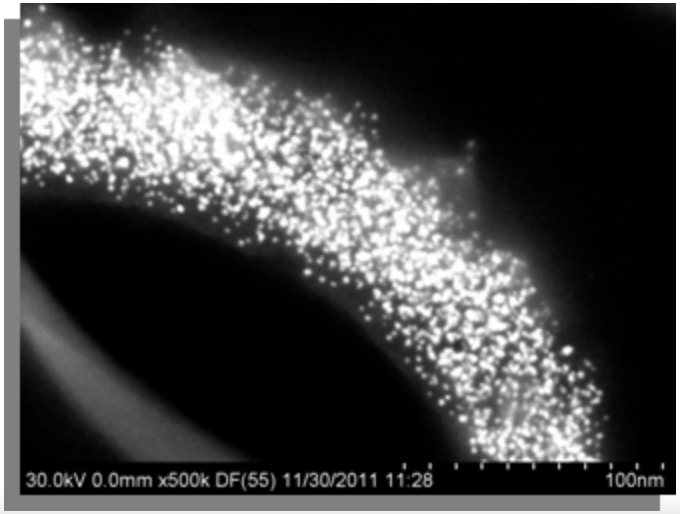
Pt on HGS substrate (HGS: hollow graphitic sphere)



TEM image of
HGS 20 wt% Pt



SEM image of
HGS 20 wt% Pt



Cross-sectional cutting of
HGS (shell) with 20 wt% Pt

Particle Properties	
- diameter:	300 nm
- wall thickness:	40 nm
- avg. pore diameter:	4 nm

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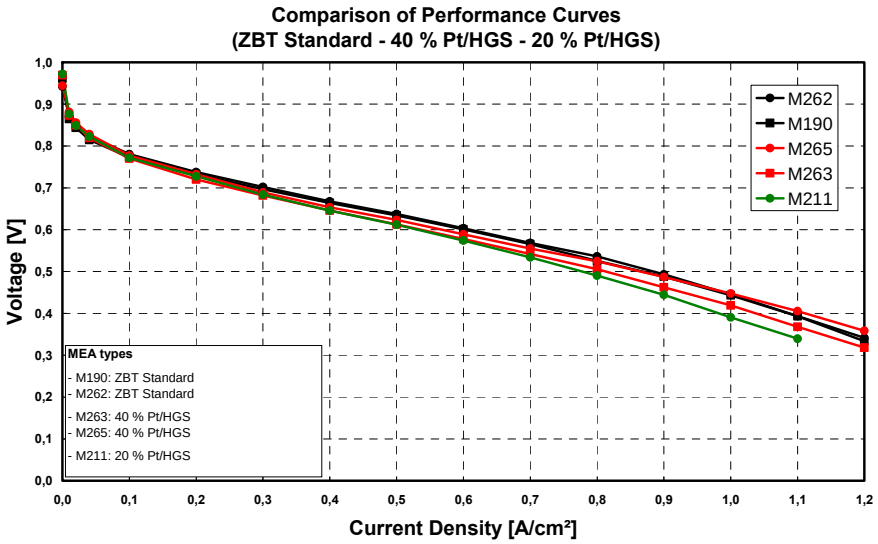
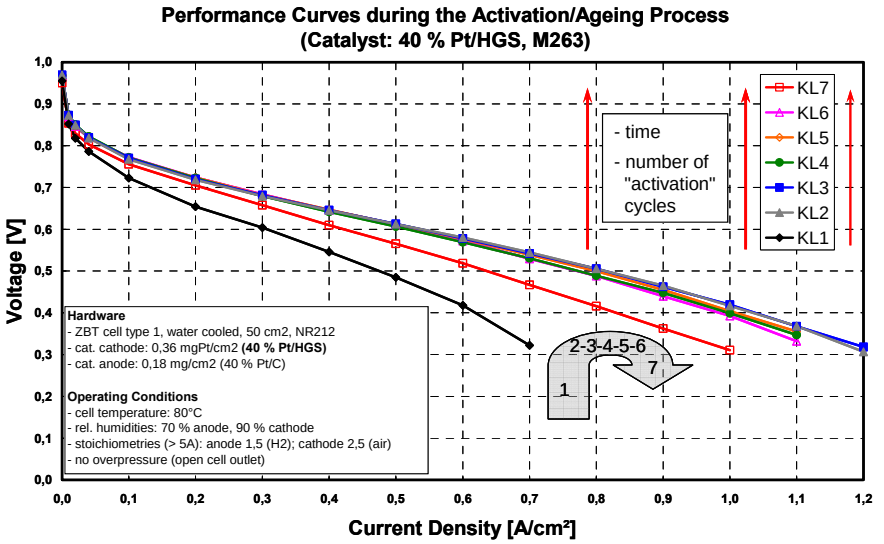
HGS Performance and Activation/Ageing (40% Pt/HGS, cath.)





Performance Results

- very good performance achieved

- M262 + M190: ZBT standard (Nafion NR212)

- M265 + M263: 40 % Pt/HGS, cathod. (Nafion NR212)

- M211: 20 % Pt/HGS, cathod. (Nafion NR212)

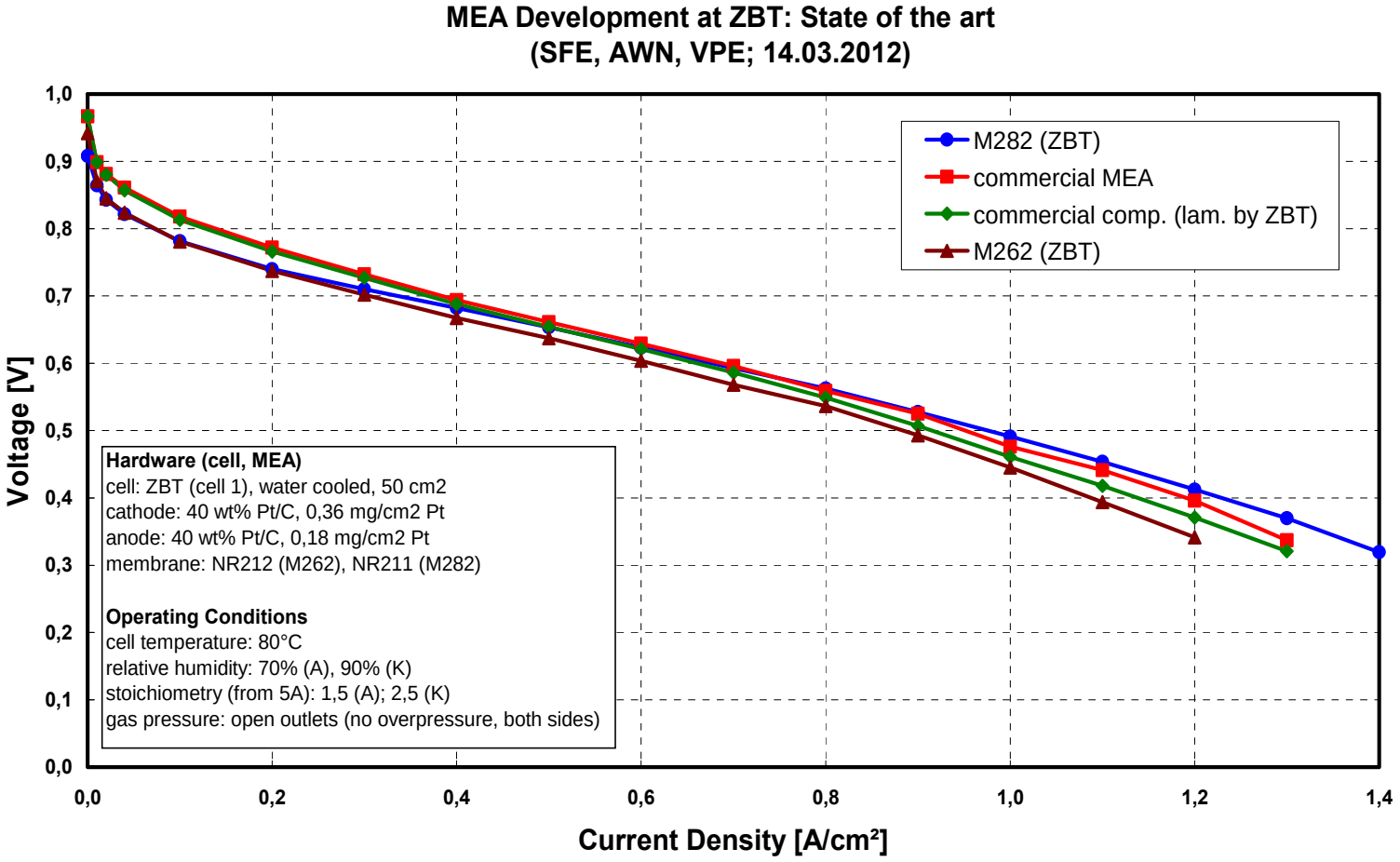
Activation/Ageing/Stability Results

- <u>catalyst activation is necessary</u>

- very good electrochemical stability (slow ageing)

- activation and ageing procedure
  - in situ CV, H_2/N_2, 80°C, 50 - 1.400 mV
  - in total: 1.000 cycles (5 x 100 + 1 x 500)

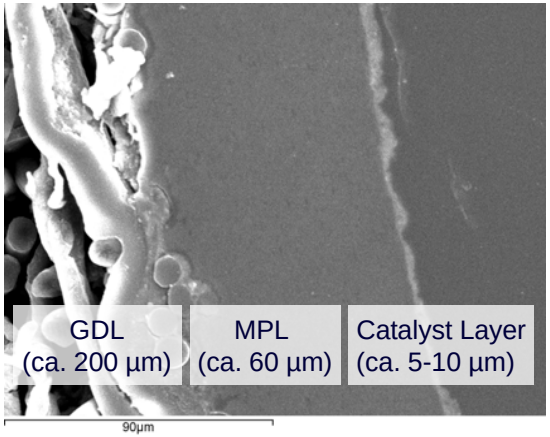
ZBT MEA Performance: State of the Art (LT MEA)



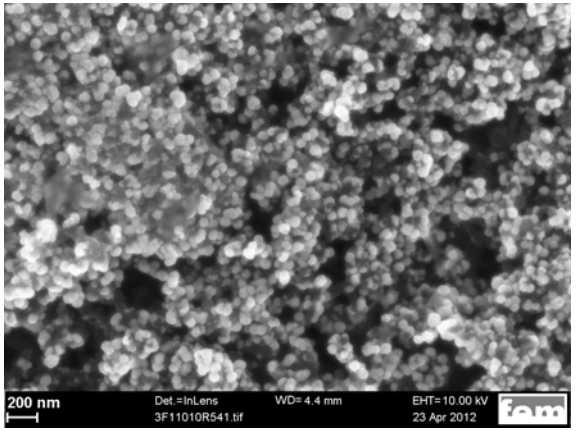
Main Results

- very good performance with ZBT MEA´s achieved
- M262:
  Nafion NR212, 50 µm
- M282:
  Nafion NR211, 25 µm
  (data not yet reprod.)
- cell type 1
  - ZBT flow fields
  - 50 cm^2

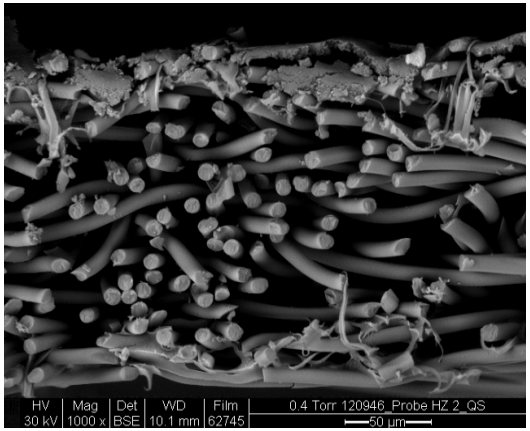
GDS Development and GDE Preparation by Galvanic Coating of GDS



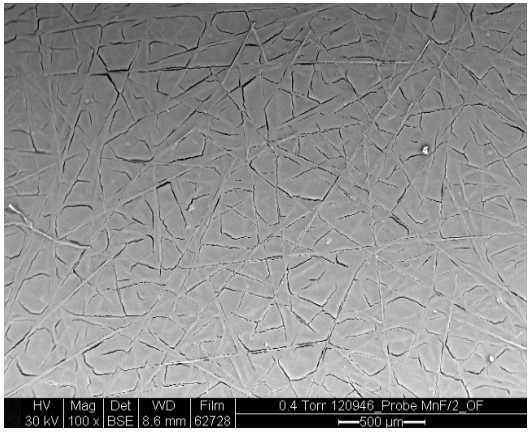
GDE Analysis - SEM/EDX
(UDE, Dr. Myronova)



GDE Development - top view on **galvanically coated** GDS (FEM, Dr. Baumgärtner, fem_189)

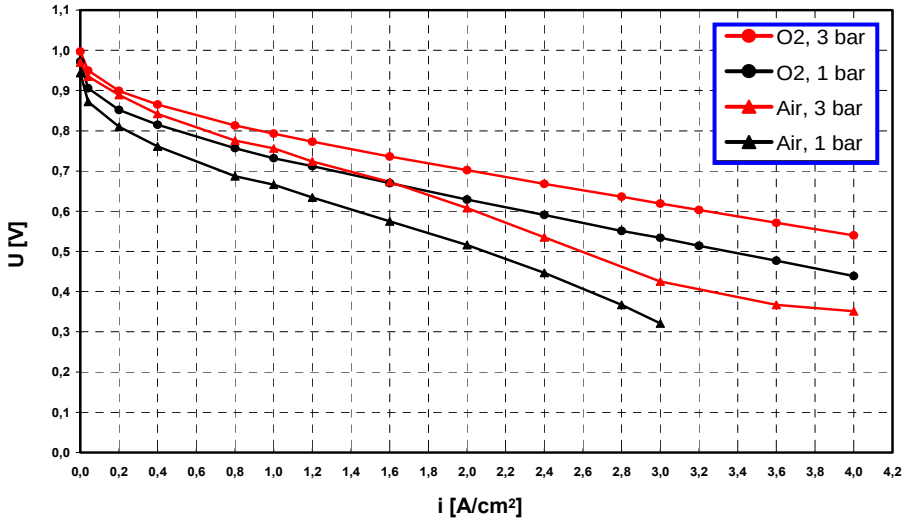


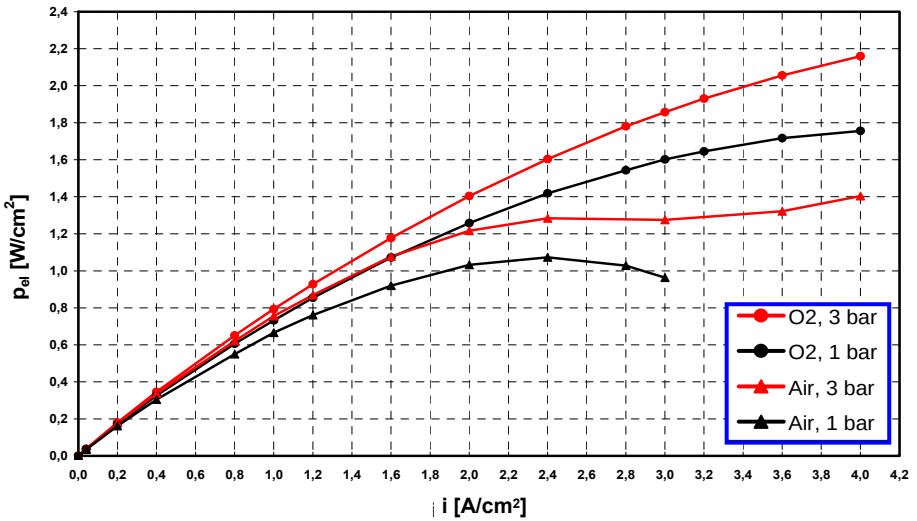
GDS Development - SEM, cross section, MPL on upper side (FILK, M. Langer)

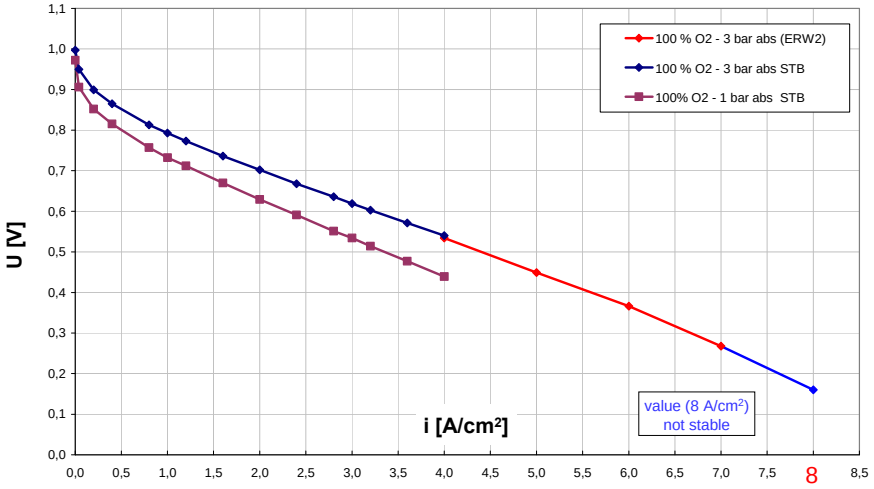


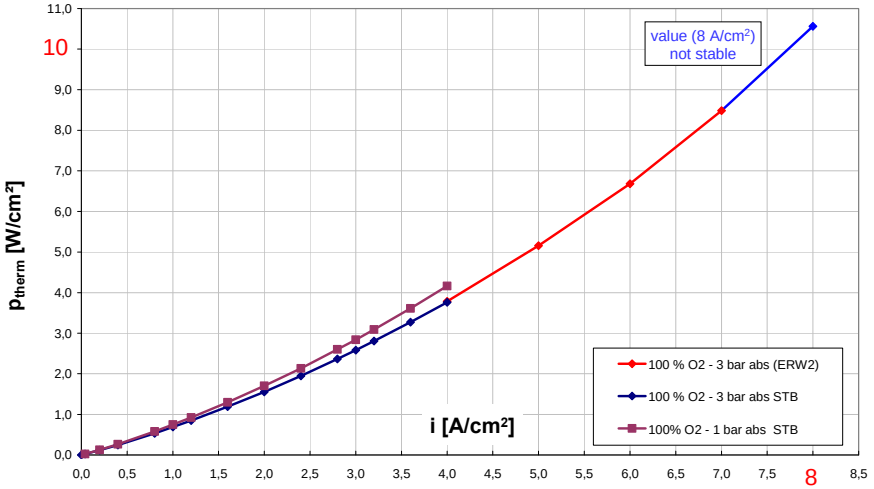
GDS Development - SEM, top view on MPL (FILK, M. Langer)

HPTC Performance for air/O_2 operation (PC MEA, LT, cell type 2, 25 cm²)







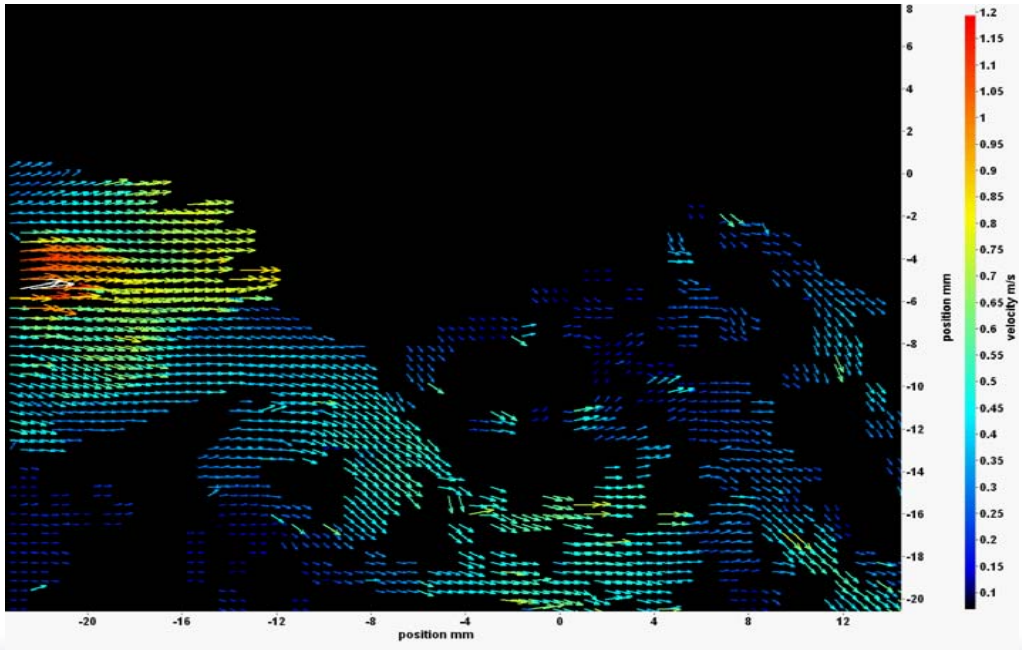


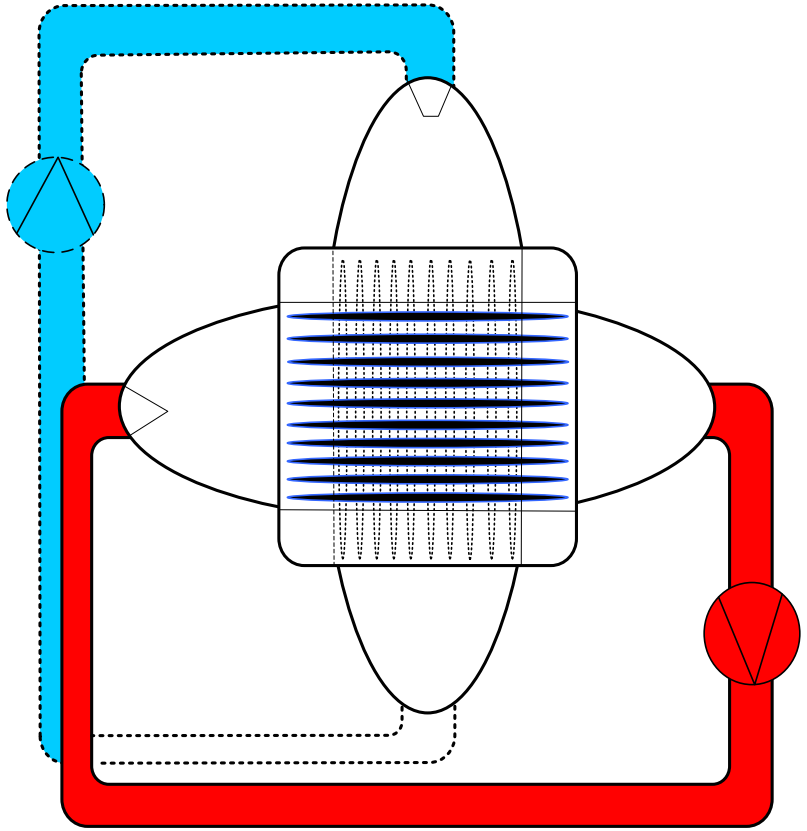
Main Results

- excellent performance achieved with PC MEA, better than with commercial MEA´s
- current densities up to
  - 4.000 mA/cm² (air)
  - 7.000 mA/cm² (O_2)
- power densities up to
  - 1.400 mW/cm² (air)
  - 2.200 mW/cm² (O_2)
- extreme thermal loads of the MEA tested (ca. 10 W/cm²)

Cell Concept Development and Component Characterization

- MT PEM cell cooling by evaporating water
  - ultrasonic water atomization
  - characteriz. by Particle Image Velocimetry (PIV)
- membrane humidification by evaporated water
- no extra coolant needed (one-piece bipolar plates)
- gas circulations
- water condensation, cloosed water loops





Thank You very much for Your attention !

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Development Teams:

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