
Center for Solar Energy and Hydrogen Research
(ZSW Ulm)
Division 3 Energy Storage and Energy Conversion

Center for Solar Energy and Hydrogen Research (ZSW)

太阳能和氢能研究中心

Baden-Württemberg, Germany

R & D of Fuel Cells in the ZSW

Dr. L. Jörissen, Dr. W. Lehnert

Dr.-Ing. Weibo ZHANG

Shanghai International Industry Fair 2004, Fair Area of Chinese MOST
Shanghai New international Expo Center, Pudong, Hall 5
Nov. 4 / 9th 2004

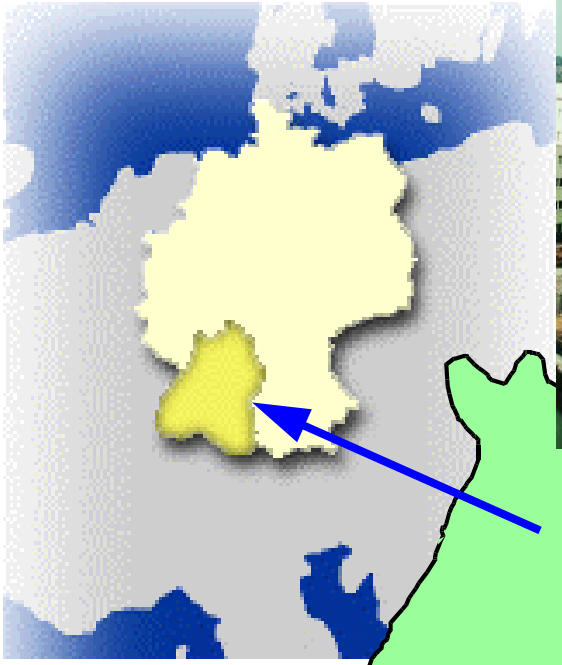
Organizational Form of ZSW

- Non Profit Foundation*
- Founded in 1988
  - GB3 in Ulm from 1990
- Founders:
  - Ministry of Economics Baden-Württemberg
  - University of Stuttgart
  - University of Ulm
  - German Aerospace Research Organisation (DLR)
  - Industry and Private Companies

*** initiated and supported by the Ministerium für Wirtschaft Mittelstand und Technologie, Baden-Württemberg**

Location of ZSW

- Stuttgart
  - Administration
  - Photovoltaic
  - Renewable Fuels
  - System Analysis
- Widderstall
  - PV-Test site
- Ulm
  - Energy Storage and Energy Conversion



Ulm
2004

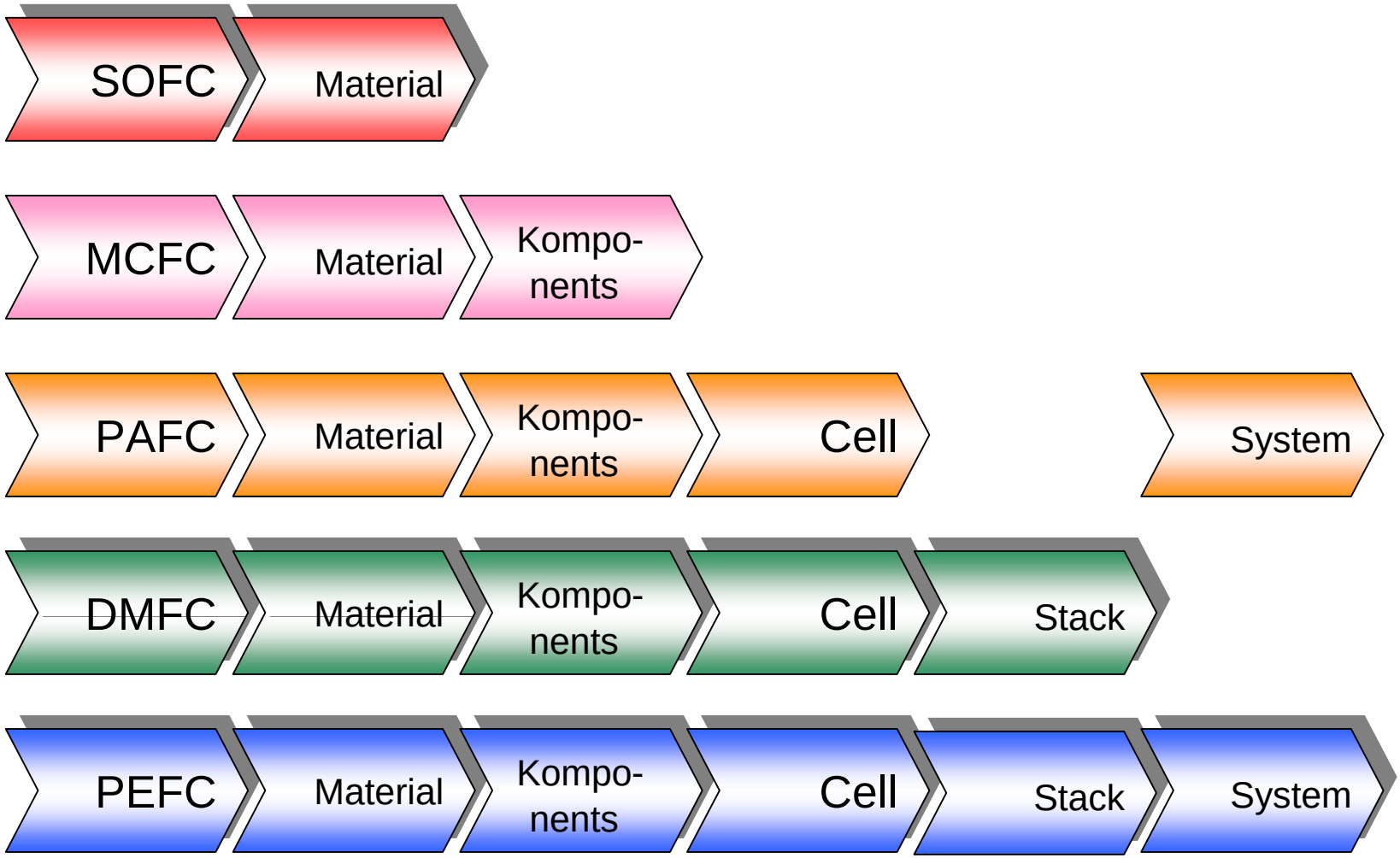
Einstein
125.

Division 3

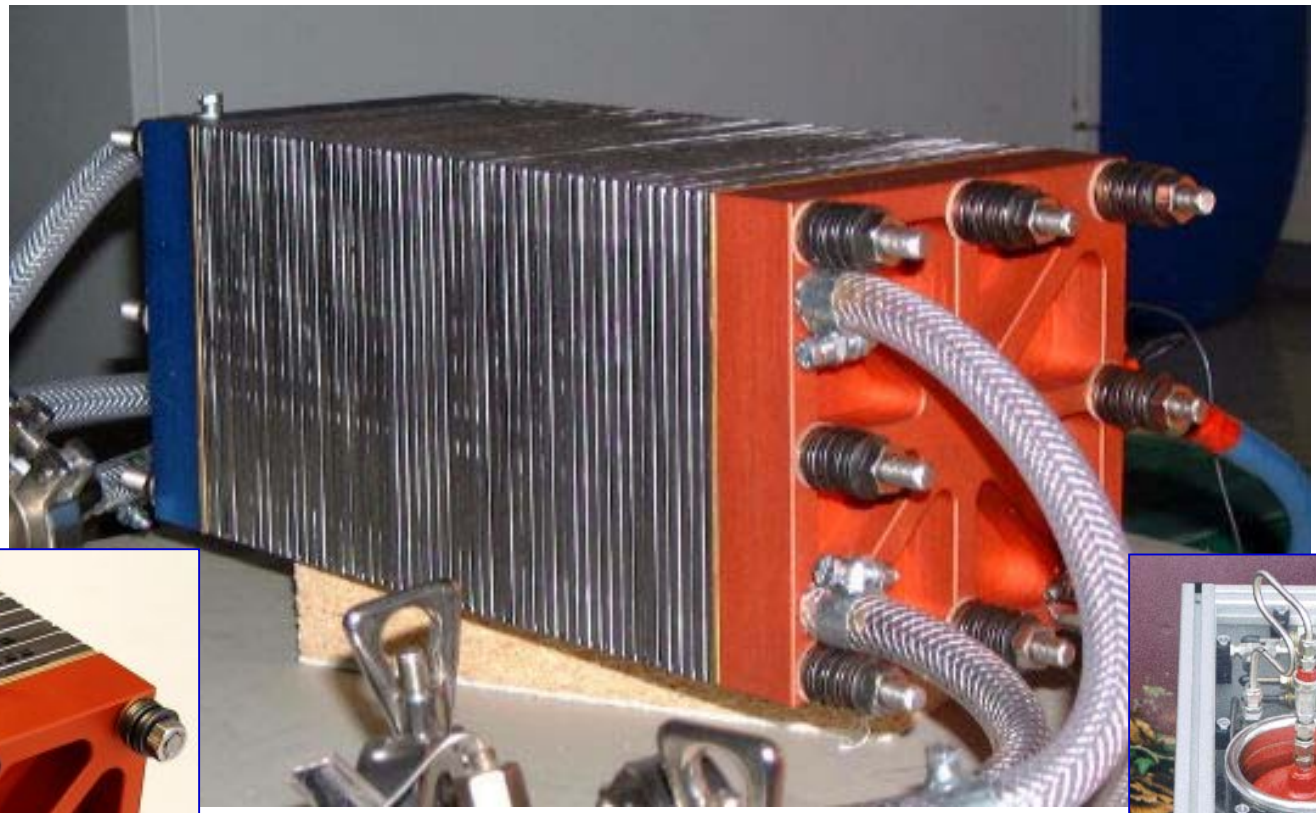
Electrochemical Energy Storage and Energy Conversion

ECM	ECA	ECW	ECV
Electrochemical Materials Development	Electrochemical Accumulators	Electrochemical Hydrogen Technologies	Electrochemical Processes und Modelling
Frau Dr. M. Wohlfahrt-Mehrens	Dr. H. Döring	Dr. L. Jörissen	Dr. W.Lehnert
Oxides as Active Materials	**Commercial Accumulators**	**PEFC/DMFC Components**	**Fuel Cells Modelling**
Alloys as Active Materials	**Performance & Safety-Tests**	**PEFC/DMFC Stacks**	**Porous Media**
Catalysts	**System Technology PV, EV**	**Hydrogen Technology** Storage, Cleaning	**Fuel Cell Research Aliance**

Fuel Cell Development at the ZSW



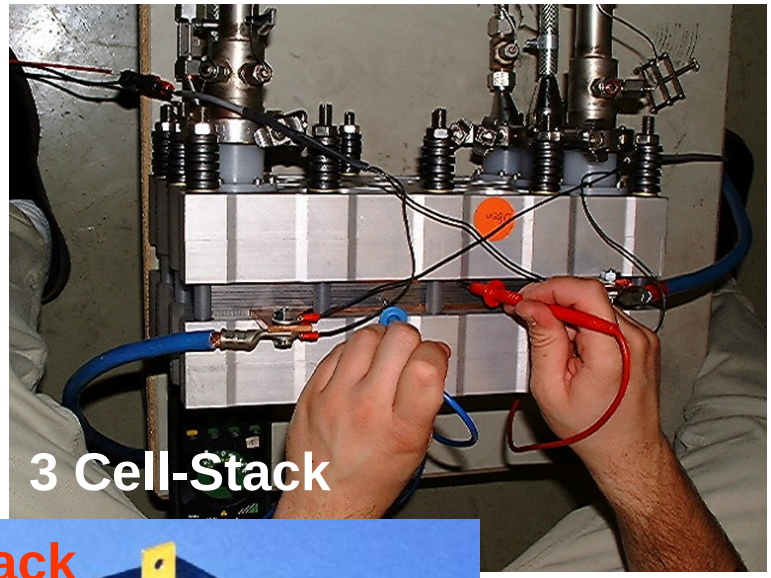
ZSW Standard Stack

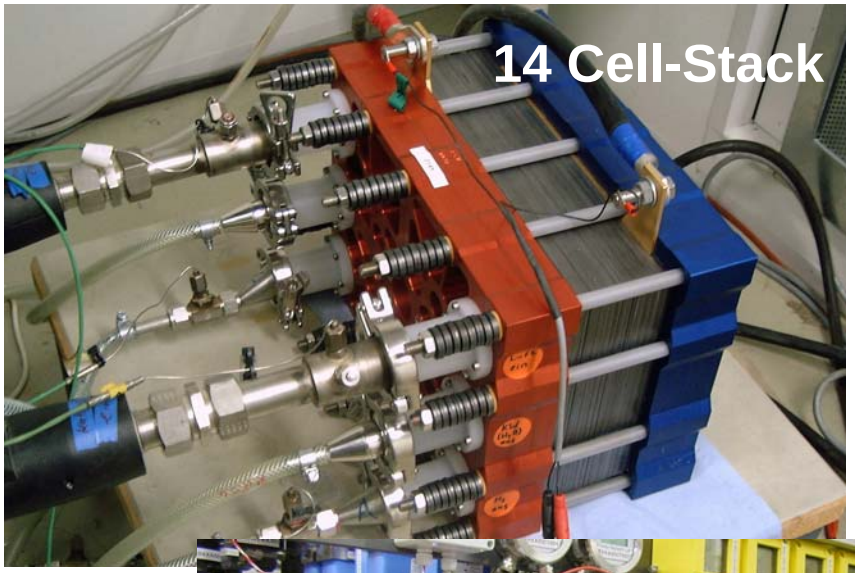


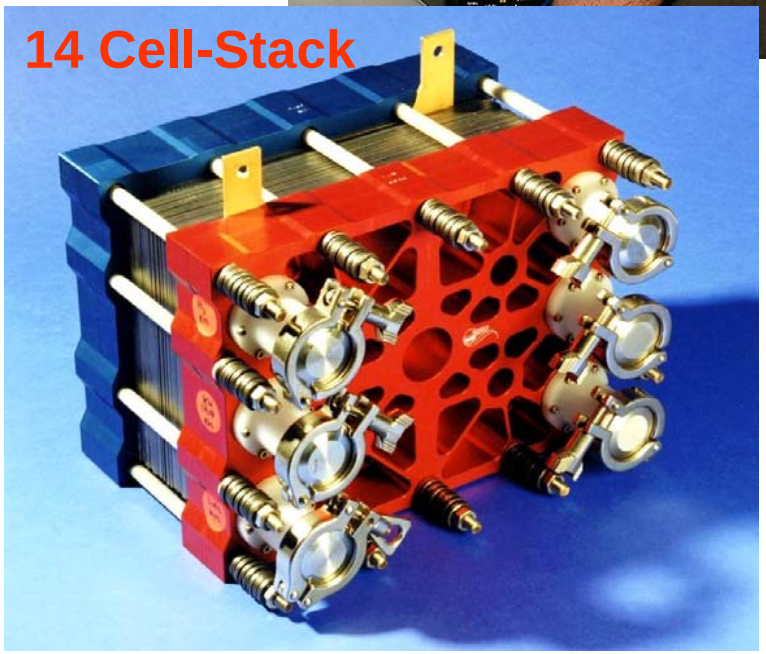
Active Area 100 cm²

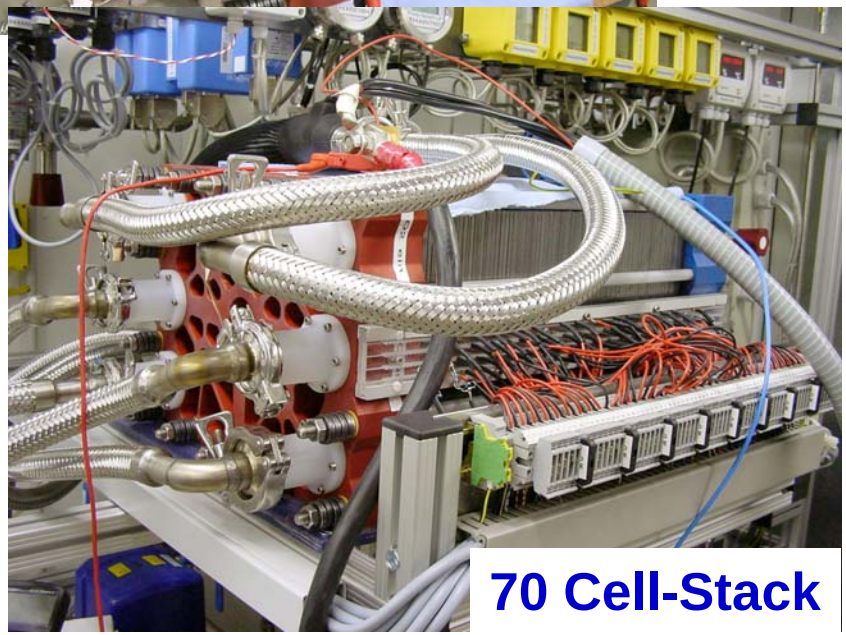
Large Area Stack

(active area 560 cm²)

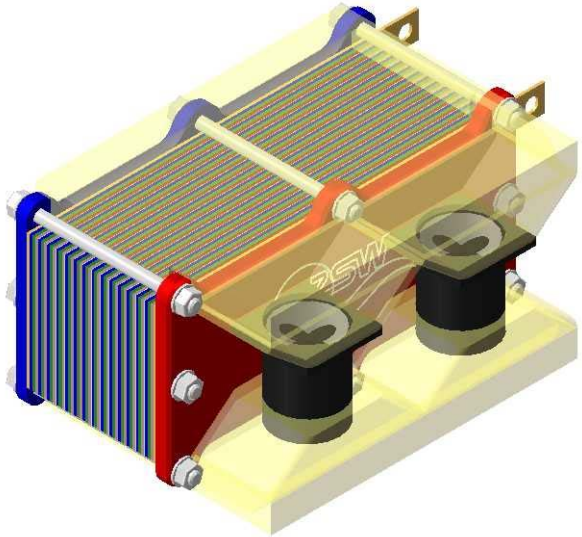






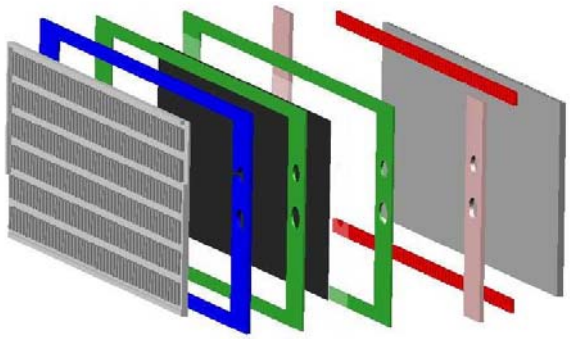


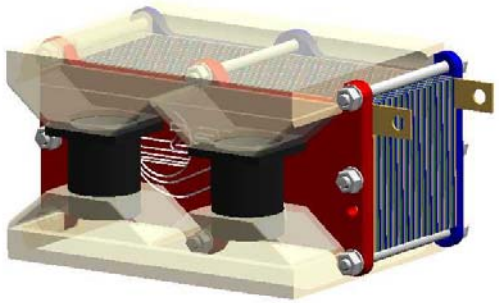
Our stacks and Products

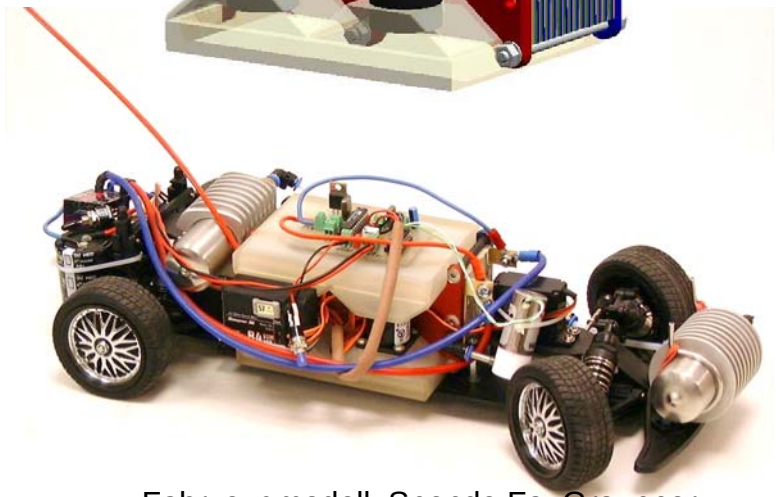


玩具用燃料电池

Low-Cost-PEFC-System







Fahrzeugmodell: Spende Fa. Graupner

- Possibly Low Cost
  - Structured GDL
  - Flat gasket
  - Metall Foil BPPe
- Fuel Cell Stack
  - 14 Cells, 7 V
  - Power: 35 / 60 W
  - Power Density: ~60 mW/cm^2
- Maintenance
  - Non permanent sealin
- Material Cost (Single System)
  - Stack: < 1.000 €
  - System: ~ 2.000 €

玩具用燃料电池

Fuel cell pocket lamp

Stack with 6 Cells
„Self-breathing“
air cooling
absolut noiseless
el. net Power : 2 W
max. el. Power : 4 W
H_2-Source : MH cartridge

燃料电池手电筒

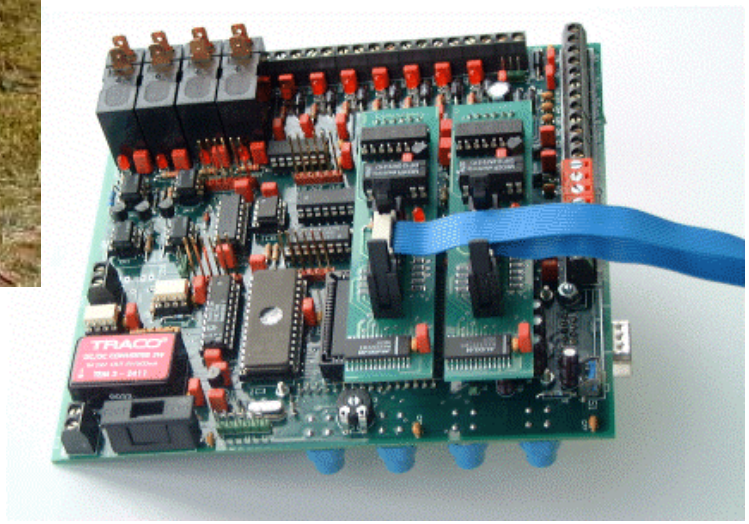
Powerbag

- **20 Zellen, 12 V DC**
- **P_{el} = 150...250 W**
- **2 l H_2-Hydridspeicherpatrone 2,0 $kWh_{chem.}$, 0,9 $kWh_{el.}$ pro Patrone**
- **H_2-Speicherpatronenwechsel mit Bajonetverschluß, Wechselzeit < 1 Minute, d. h. quasi - kontinuierlich**
- **Umluftbefeuchtung**
- **Betrieb mit H_2-Rezirkulation „dead-ended“- 100 % Gasausnutzung**
- **but P_V = 120 W**

PowerBag XL

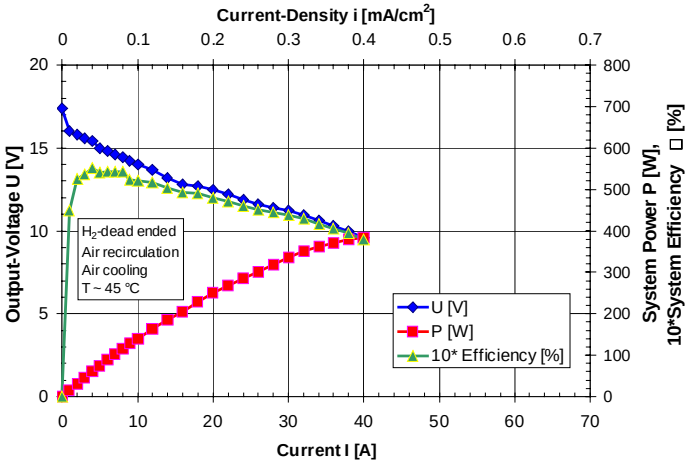
(48 cell stack, low pressure, low temperature, high efficiency, easy to handle)

Micro-Processor controlled



Elec. net power (DC):	**1100 W**	**(26V @ 40A)**
max Power :	**1300 W**	
Electric loss for auxiliary	**< 50 W_{el}**	
Weight:	**58 kg**	

Power (Bag) Boot



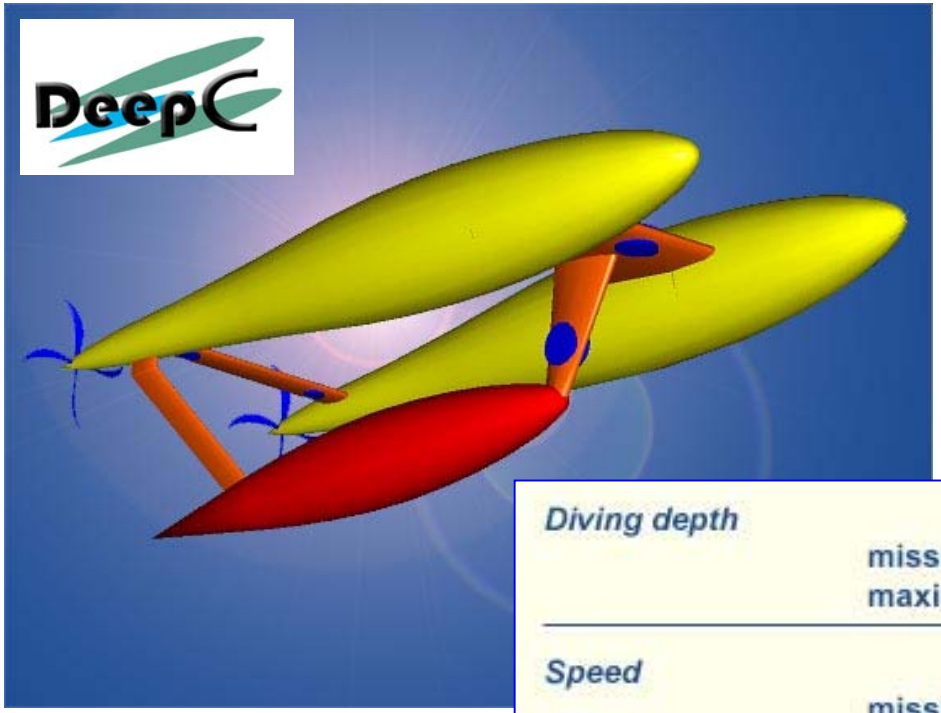
What is here drived with FC from ZSW ?

Our Solarboot with FC

http://www.solarboot-ulm.de/index.shtml

无人深海潜艇 Deep C

(Fuel Cell System for Autonomous Underwater Vehicles, AUV)



H_2/O_2-System

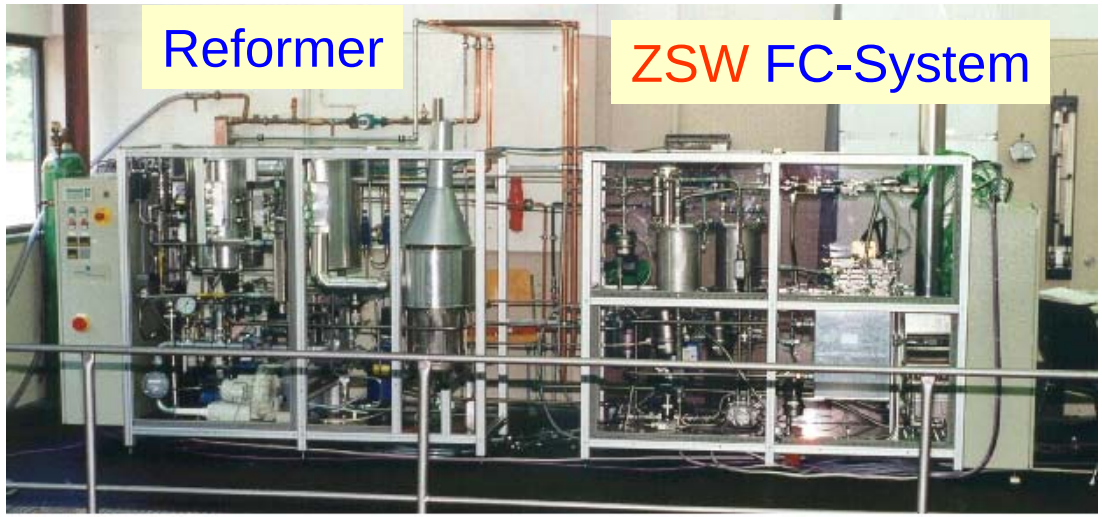
- **Two Modules**
- **1,8 kW / Module**
- **2 Stacks**
  - **30 Cells**
  - **900 W/Cell**

Diving depth	mission maximum	4000 m 6000 m
Speed	mission maximum	4 kts (0.5 kts rearward) 6 kts
Mission duration		60 hours (at 4 kts)
Mission range		approax. 400 km
Payload		300 kg
Weight (in air)		2.4 tons
Pressure Hull Material		CFRP

Fuel Cell drived Scooter

3 Generations

Advance of the Development



ZSW / ISE

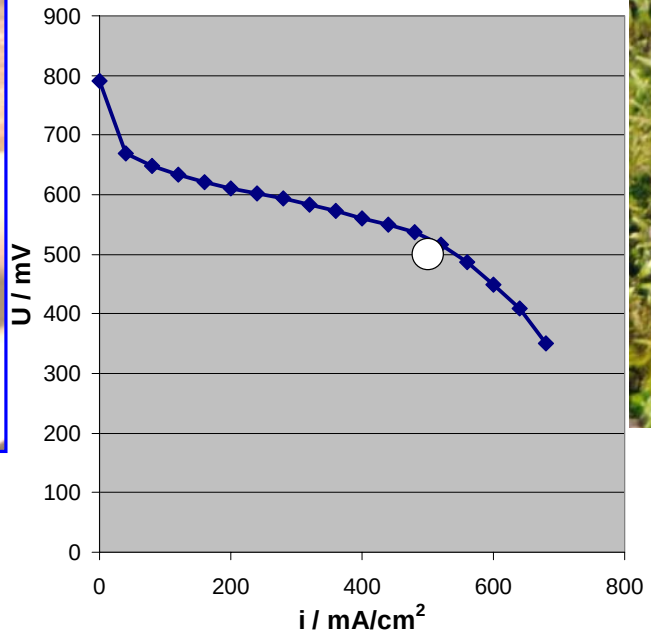
Baujahr	1999
Standort:	Fachhochschule Ulm
Reformer:	FhG-ISE
BZ-System:	**ZSW**
Maße lxbxh:	5000 x 700 x 1500 mm

PREIS DER DEUTSCHEN GASWIRTSCHAFT 2000

Viessmann Entwicklungs-Konsortium

Baujahr	2003
Präsentation:	ISH 2003
Gesamtsystem:	Viessmann
Maße lxbxh:	ca. 800 x 800 x 1200 mm

Direct Methanol Fuel Cell



Fuel Cell Test Center

(Gas Infrastructure, can feed up to 120 kW fuel cells)

- **Hydrogen (3.0)**
  - **from Electrolysis**
  - **95 m³**
  - **45 bar**
- **Oxygen (2.5)**
  - **liquid 10 m³**
  - **Evaporator 100 m³/h**
- **Nitrogen (4.8)**
  - **liquid 50 m³**
  - **Evaporator 650 m³/h**
- **CO_2-Tank**
  - **liquid 17 m³**
  - **Evaporator 100 m³/h**
- **CO / CH_4 supply**

  - Cylinder 12 m³
- **Methanol Tank 1 m³**

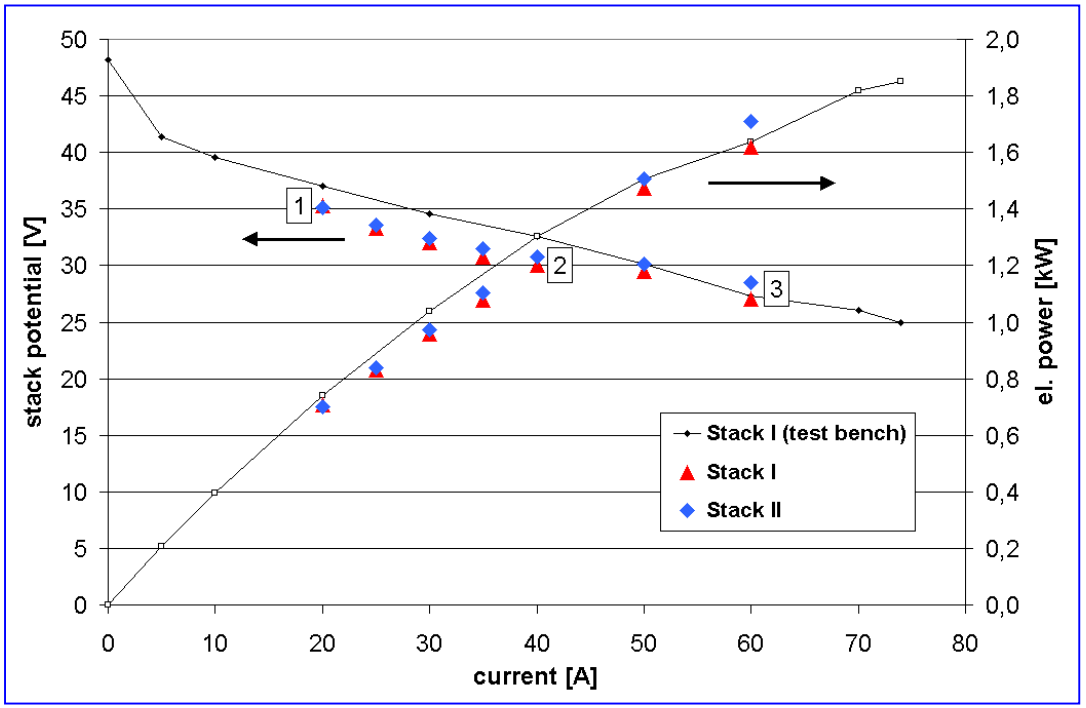
FC Test System

Stack gross power:

1: 700 W_{el}
2: 1200 W_{el}
3: 1600 W_{el}

"Kassel" system
2 stacks, each with 50 cells

Operating point
1: 35V (700mV) @ 20A (0,16A/cm²)
2: 30V (600mV) @ 40A (0,32A/cm²)
3: 27V (540mV) @ 60A (0,48A/cm²)

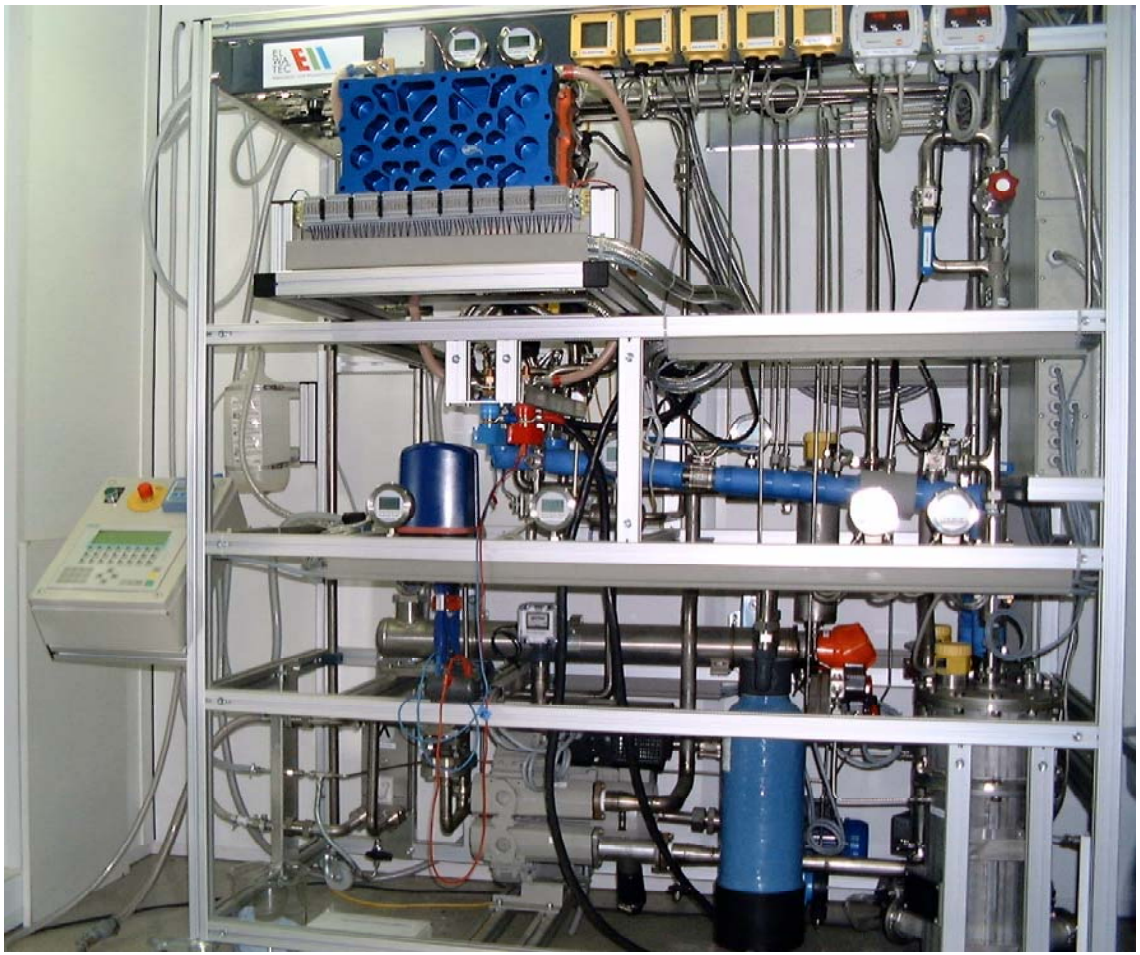


1 kW PEMFC Test System

(TU Magdeburg)

- H_2/O_2- and H_2-air operation
- Humidification, H_2-Recycling
- Pressurized operation
- PLC-Control
- Automaic operation
- Communication via Profibus®
- Pressure and pressure difference control
- Voltage control
- Safety interlock

Test Benches



Type		count	kW
PEFC	manual	5	0.5
PEFC	automatic	4	1
PEFC	automatic	2	3
PEFC	automatic	4	10
PEFC	automatic	1	120
DMFC	automatic	1	

- Temperature controlled test chamber (-25 – +30°C)

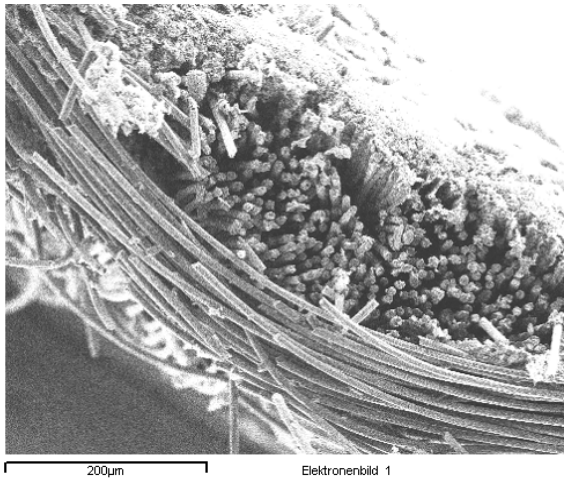
2 – 10 kW PEMFC-Test Bench

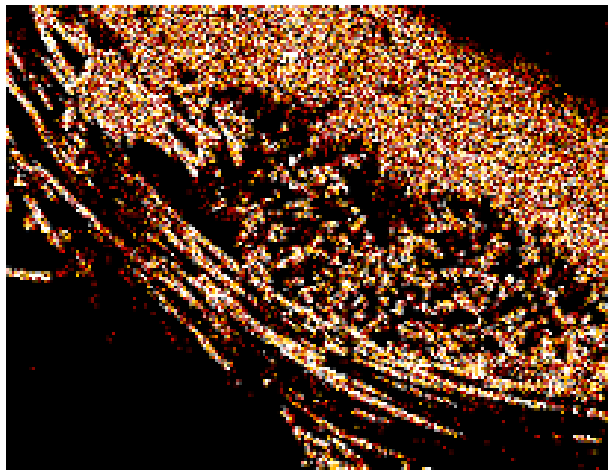
(Operation on H_2 and simulated Reformate)

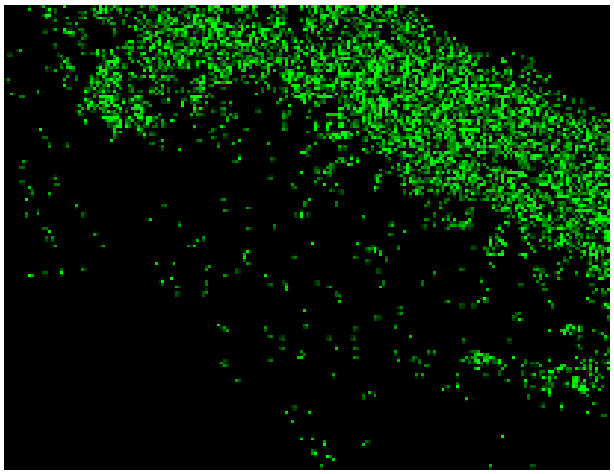
Scanning Electron Mikroscop / EDX

Distribution of
- **carbon**
- **Fluorine**

in a Gas Diffusion Layer







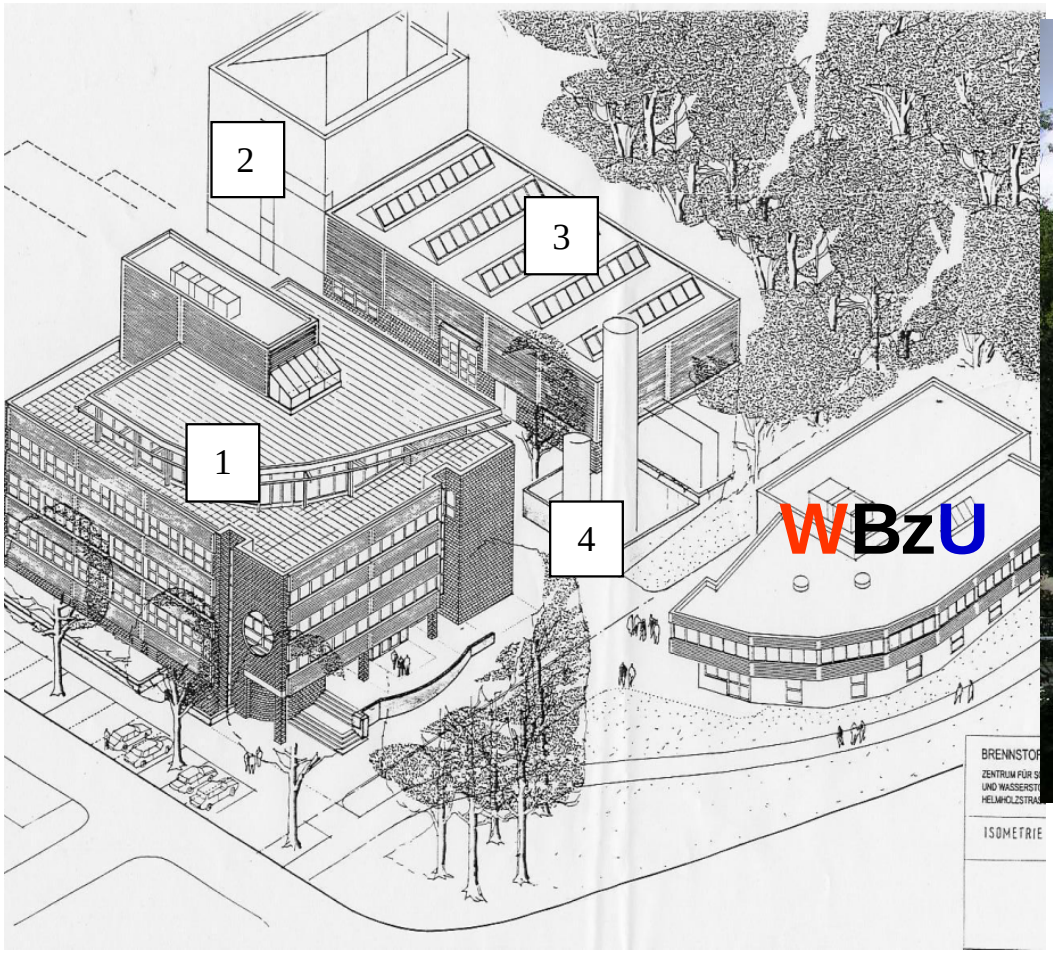
Fuel Cell Education Centre in Ulm

WBzU

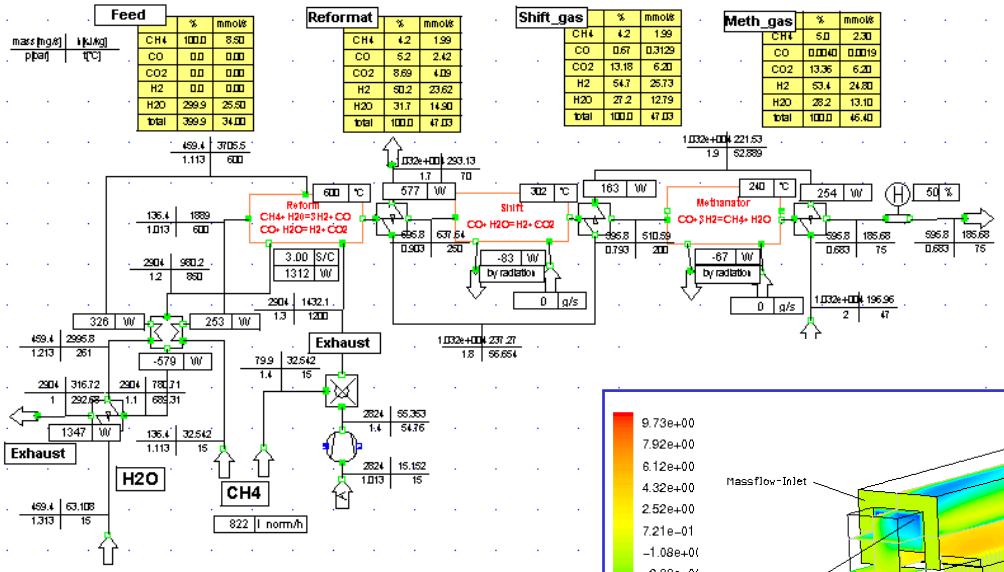
燃料电池培训中心

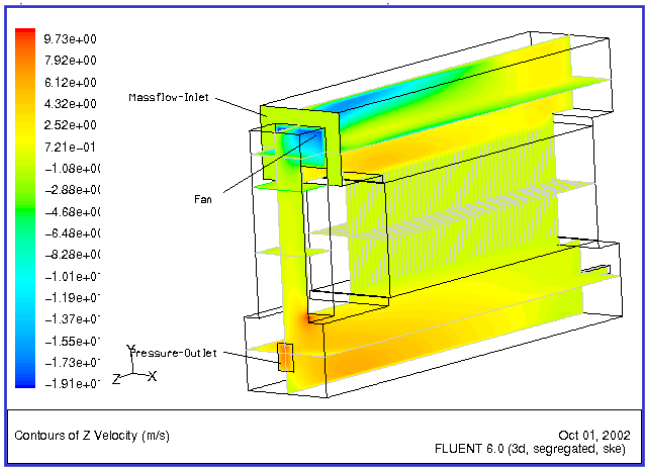
FC - Complex ULM

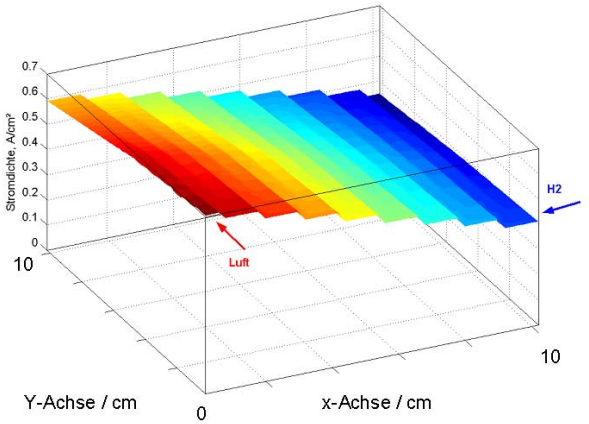
FC Training and Education Center Ulm



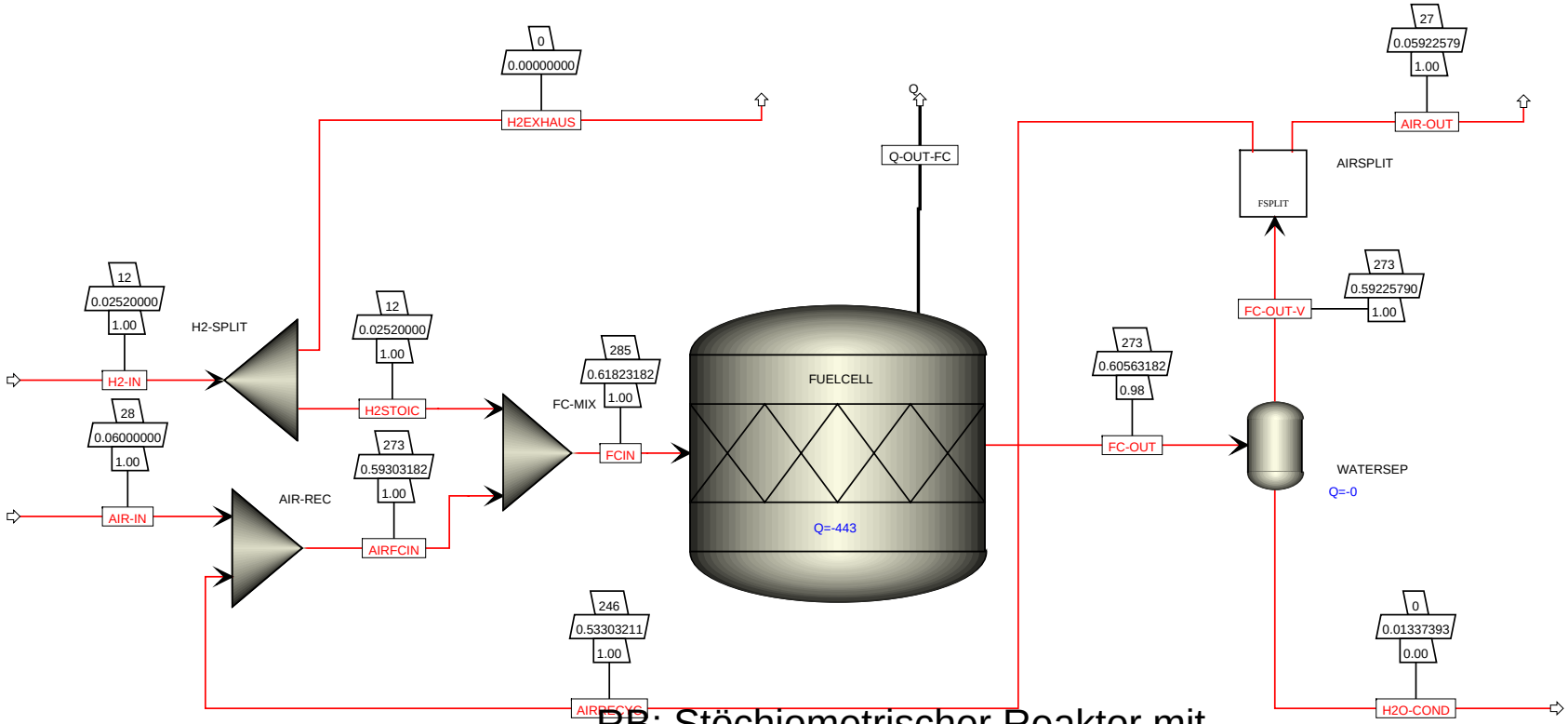
Simulation from Systems to Components







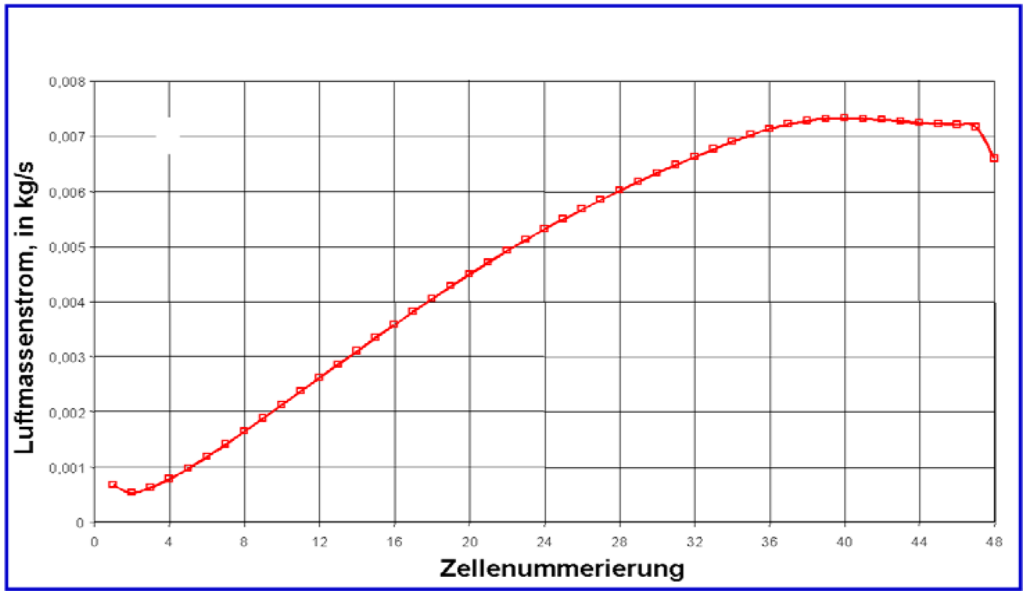
Aspen Schema for a FC-System

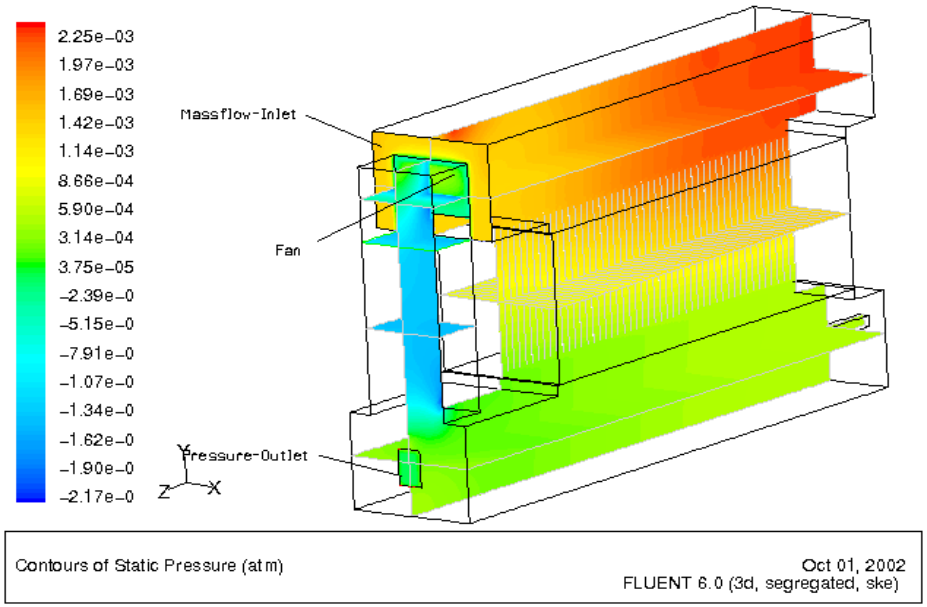


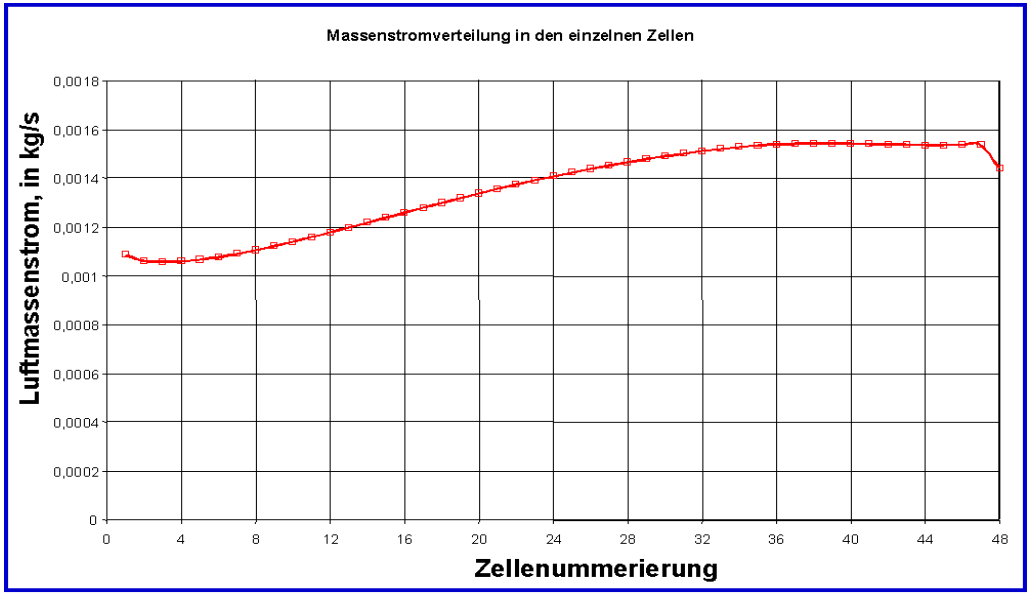
RB: Stöchiometrischer Reaktor mit 100% Umsatz in bezug auf H_2, isotherm, isobar

	Volume Flow Rate (l/min)
	Molar Flow Rate (kmol/hr)
	Vapor Fraction
Q	Duty (cal/sec)

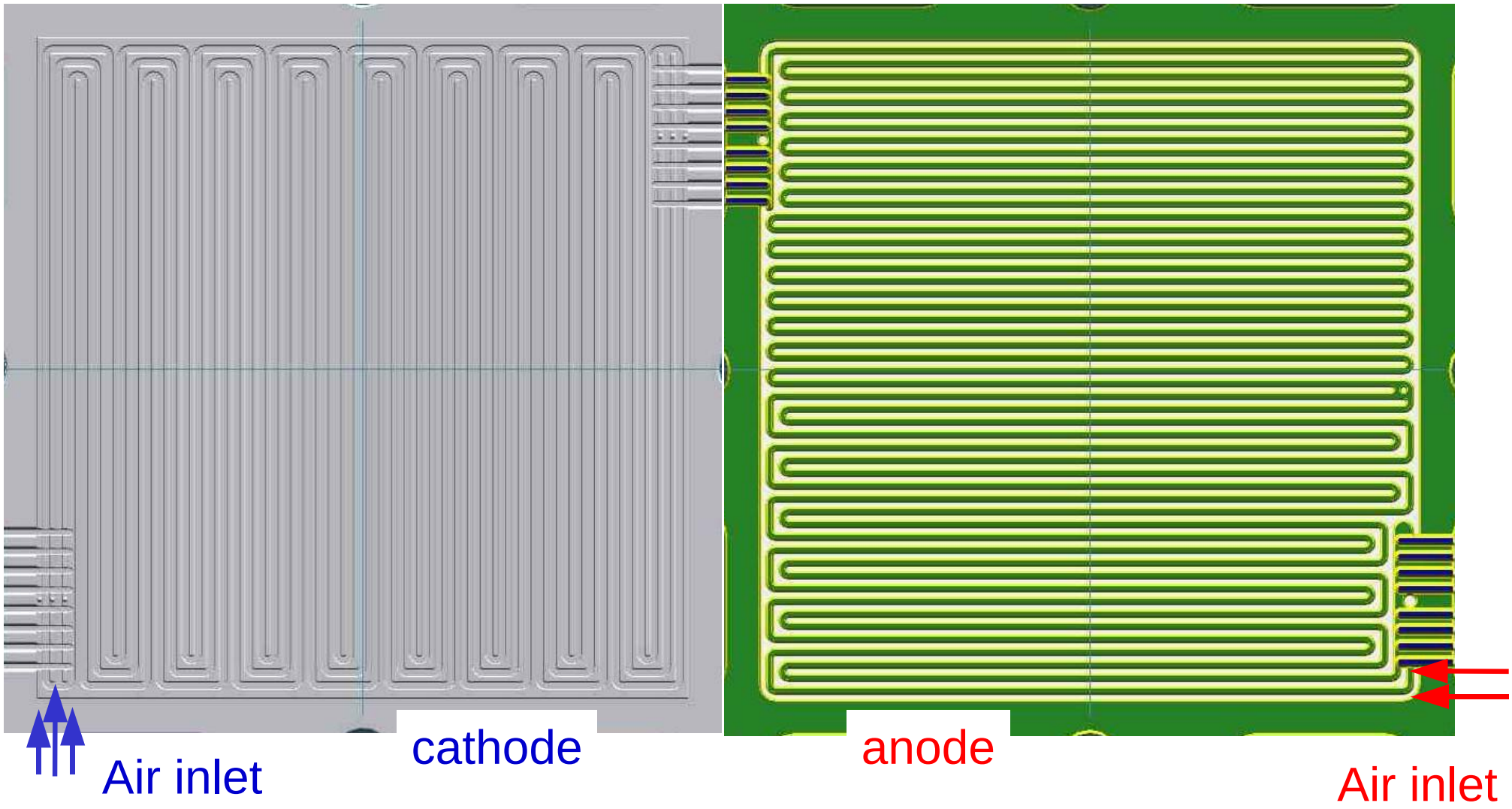
Optimal of flow distribution in Powerbag

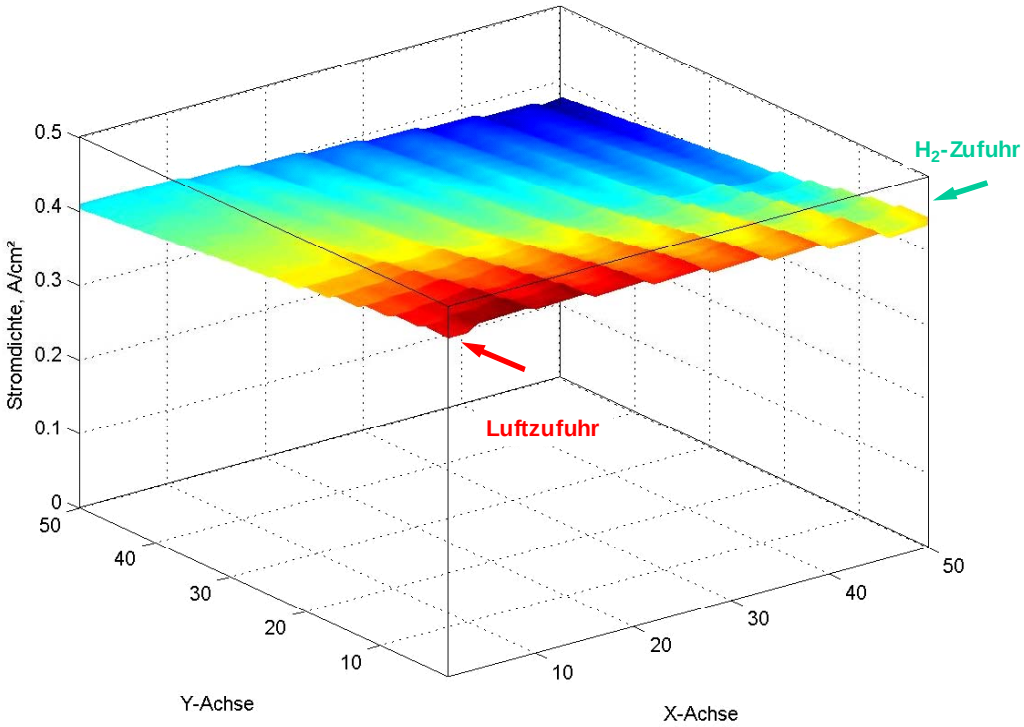




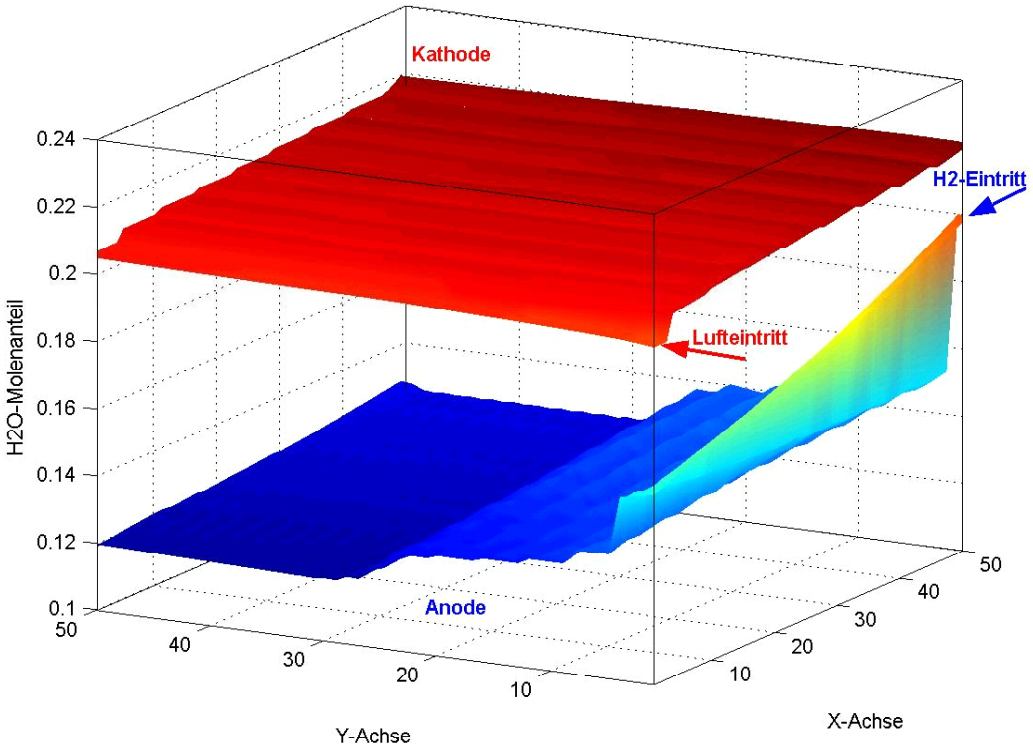


Flowfield of anode and cathode of ZSW-Standard cell





Distribution of H_2O on the electrodes

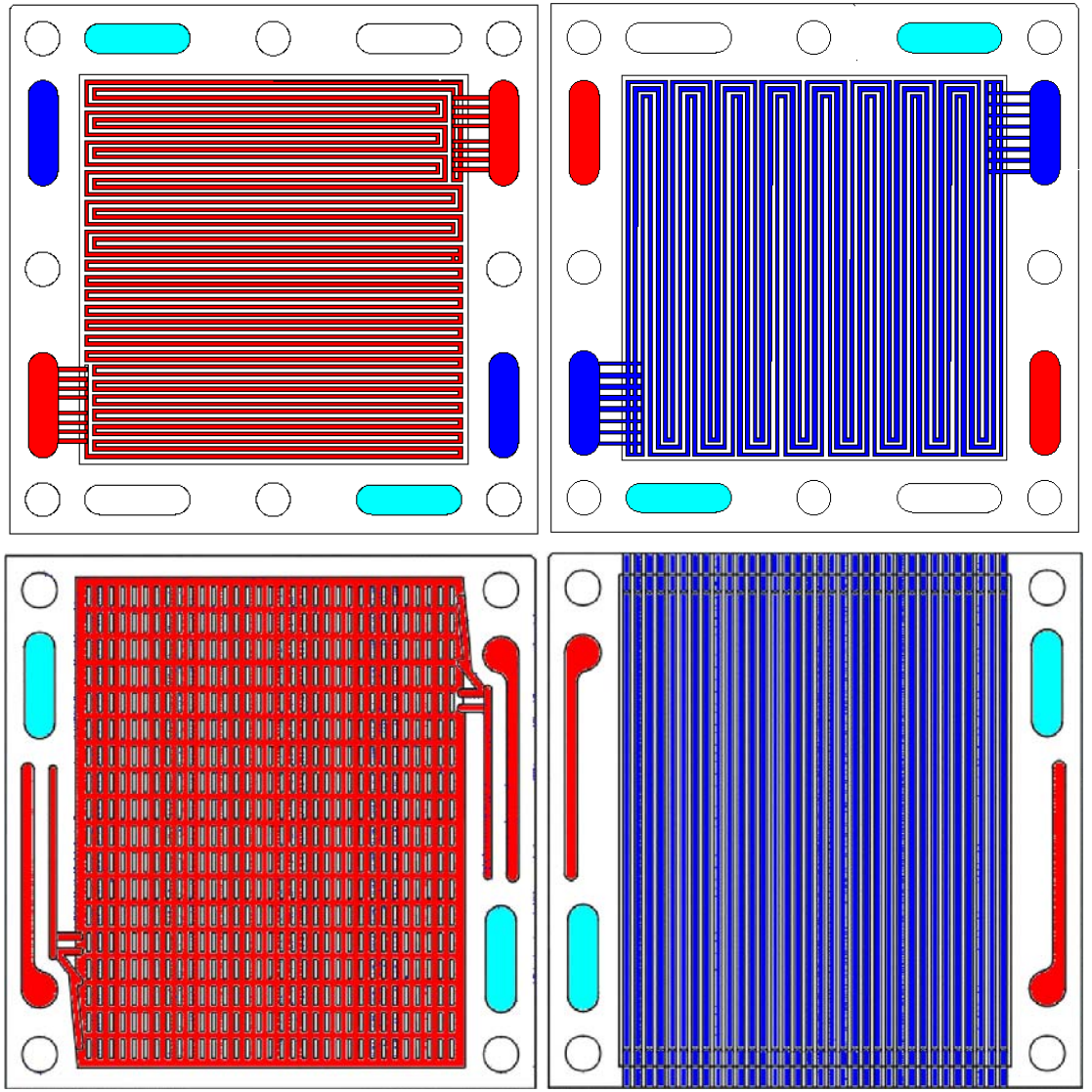


Distribustion of current density

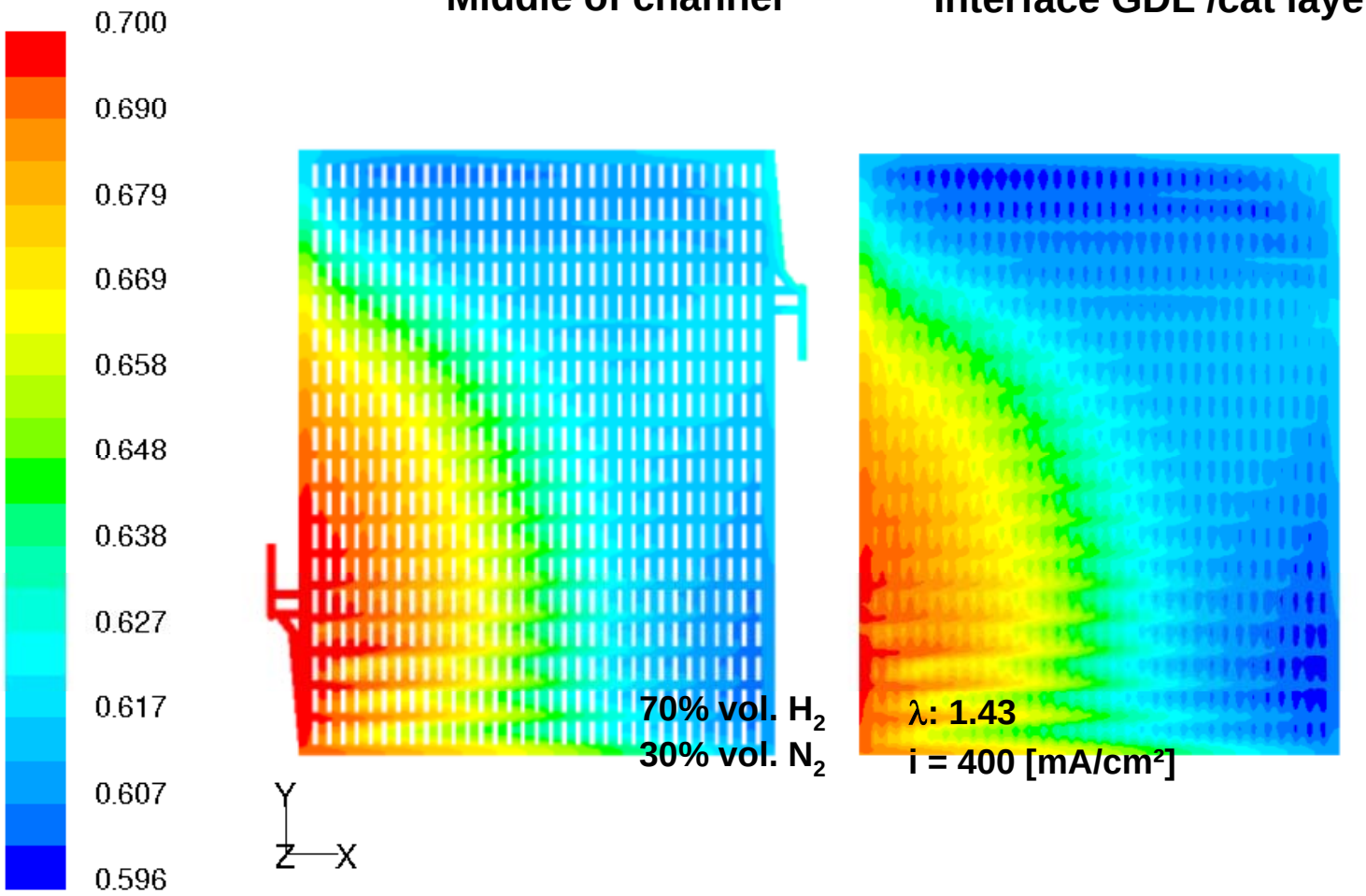
Flow field

- internal manifold
- meander structure
- pressure drop
- 100 cm^2
- water cooled

- cathode: open
- anode: pattern
- very low pressure drop
- “dead ended”
- 130cm^2
- water cooled



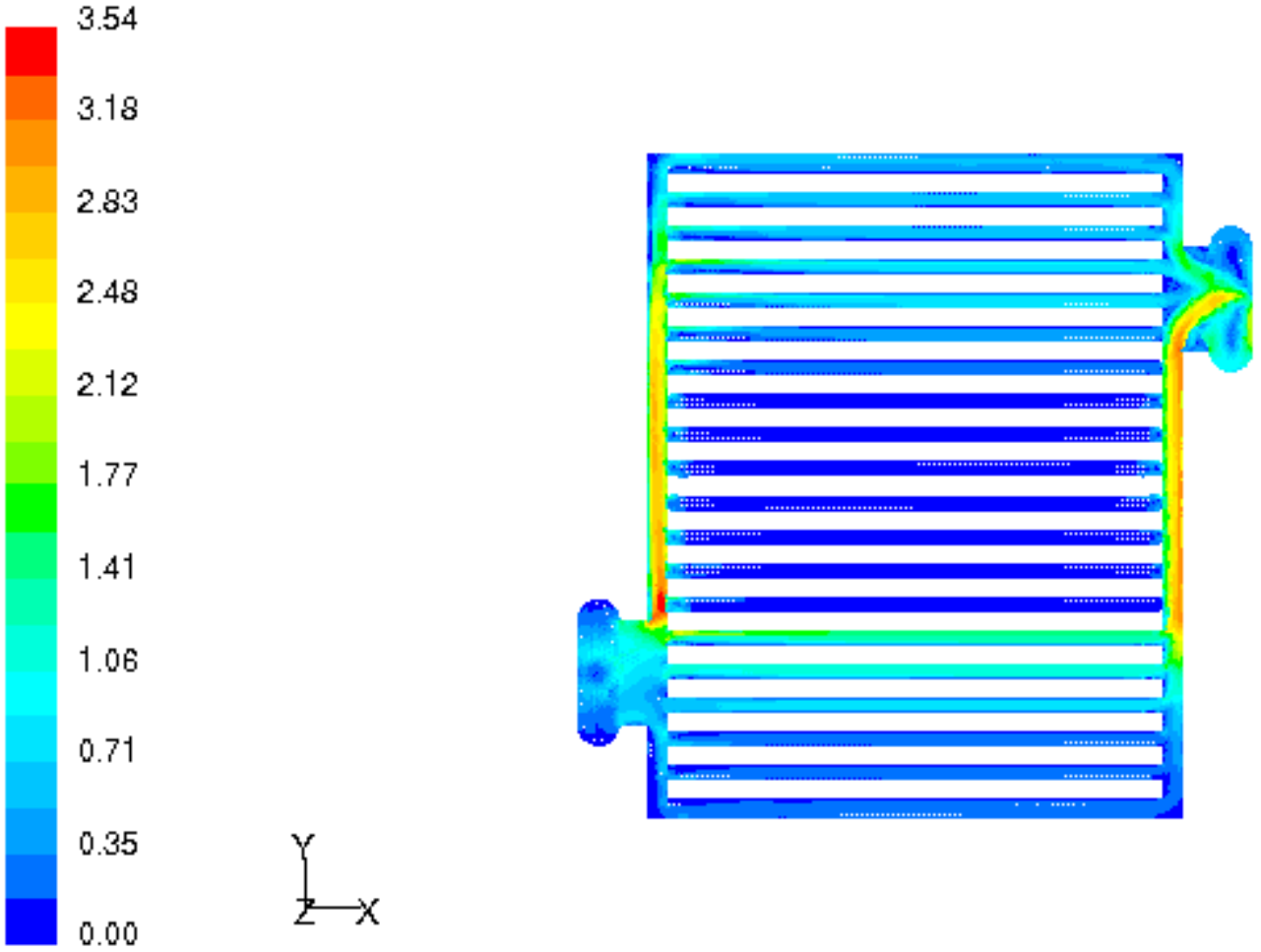
Mole fraction



Contours of Mole fraction of h2

Jul 02, 2002
FLUENT 6.0 (3d, segregated, spe2, lam)

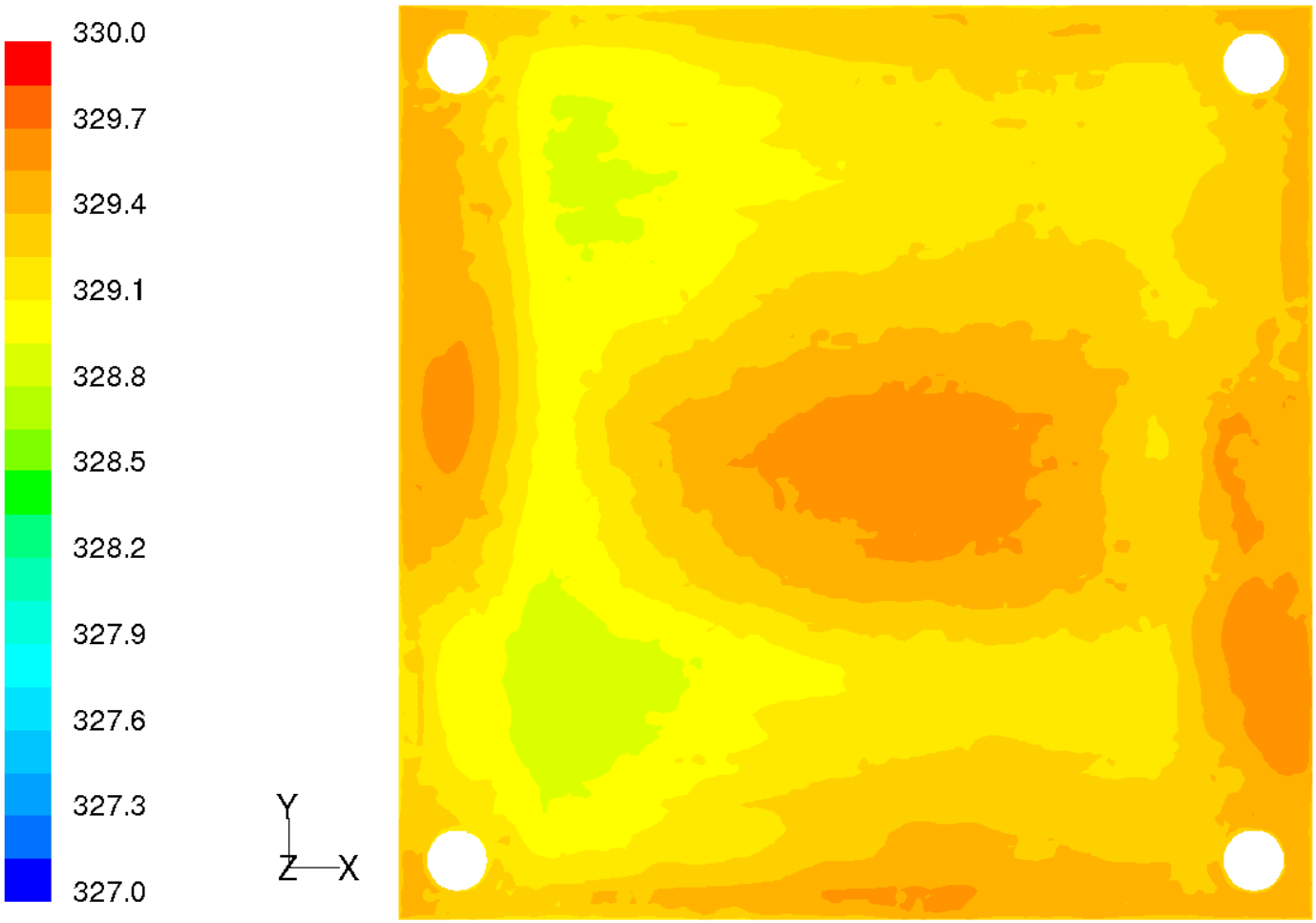
Cooling flowfield velocity distribution



Velocity Vectors Colored By Velocity Magnitude (m/s)

Sep 10, 2002
FLUENT 6.0 (3d, segregated, lam)

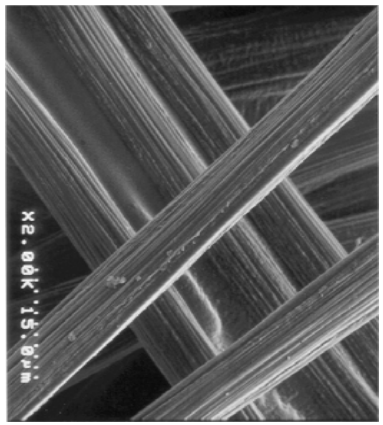
Cooling flowfield temperature distribution

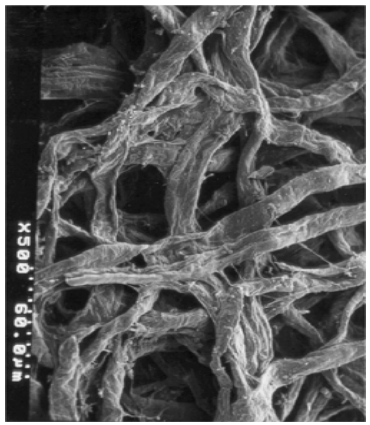


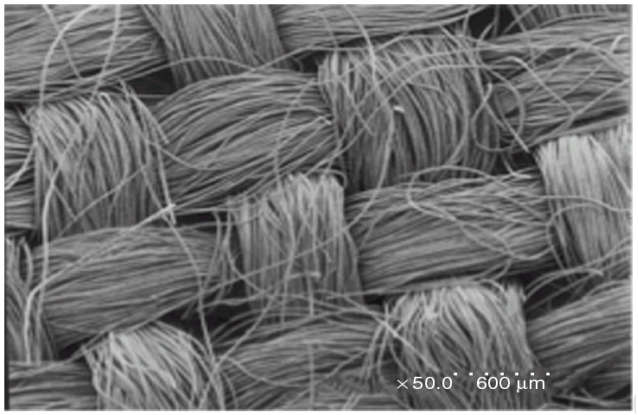
Contours of Static Temperature (k)

Sep 10, 2002
FLUENT 6.0 (3d, segregated, lam)

GDL / MEA structure

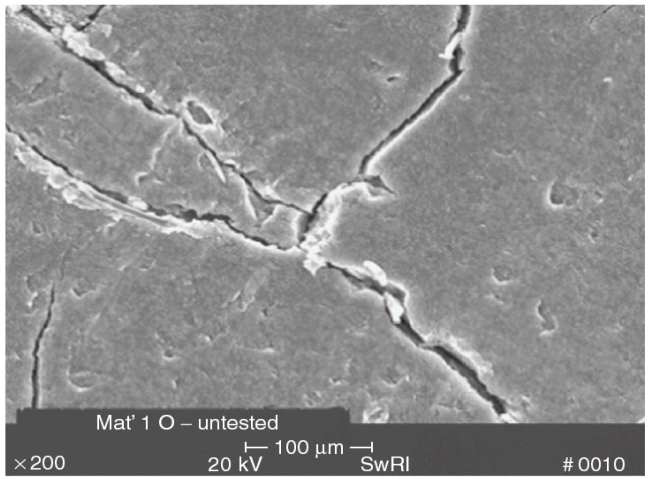




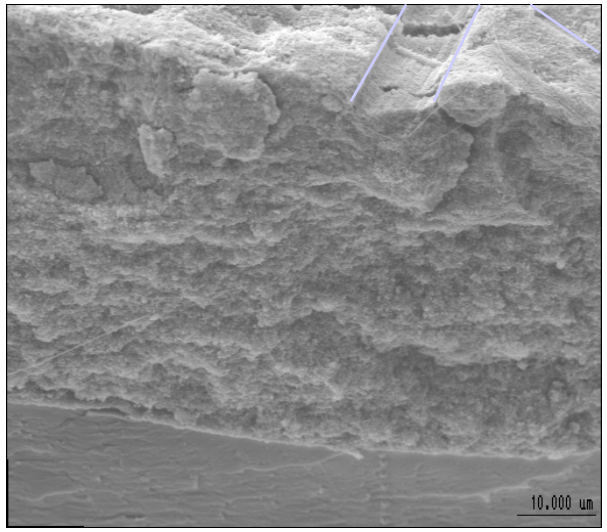


different GDLs

Mathias, Roth, Fleming, Lehnert, handbook of fuel cells ,2003

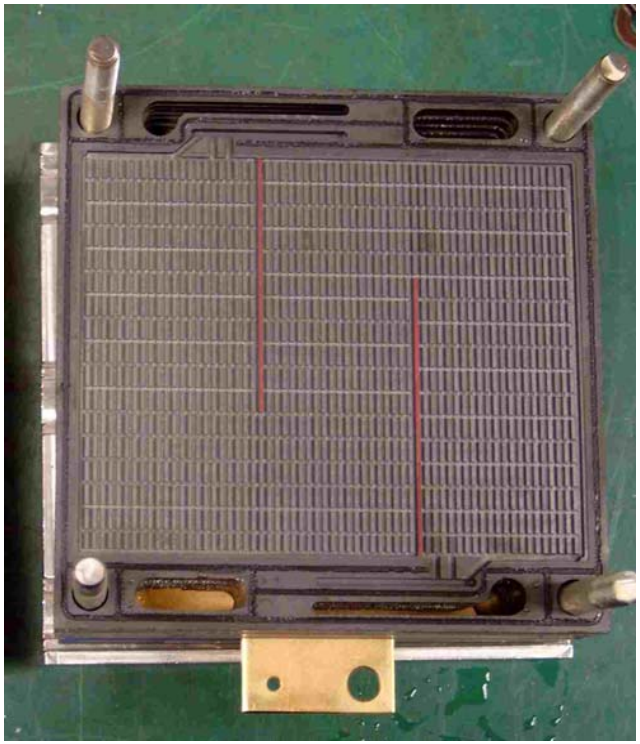


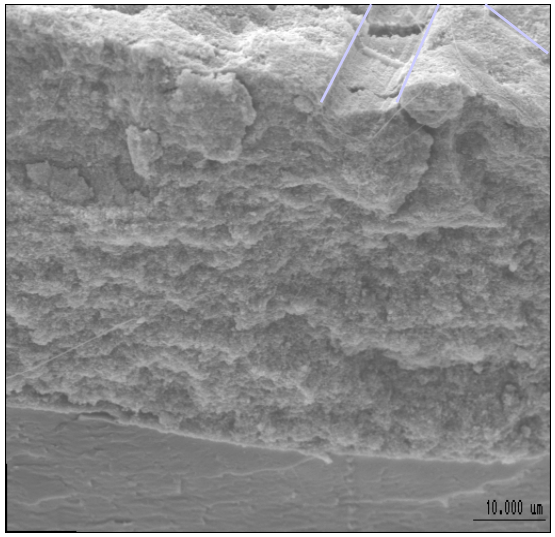
Microlayer



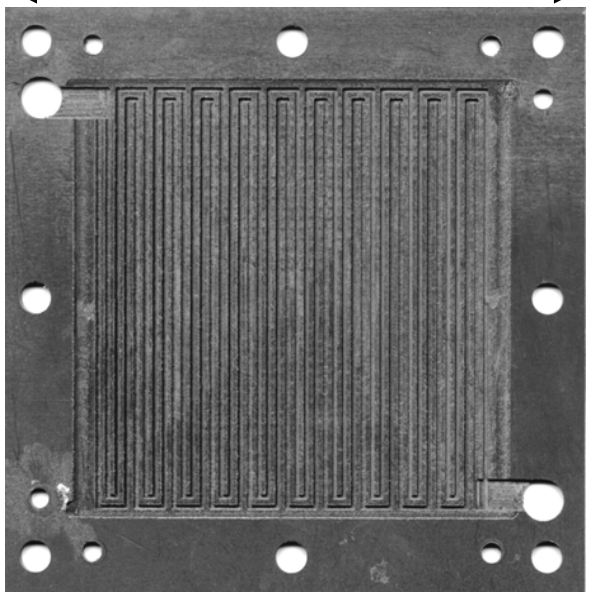
MEA

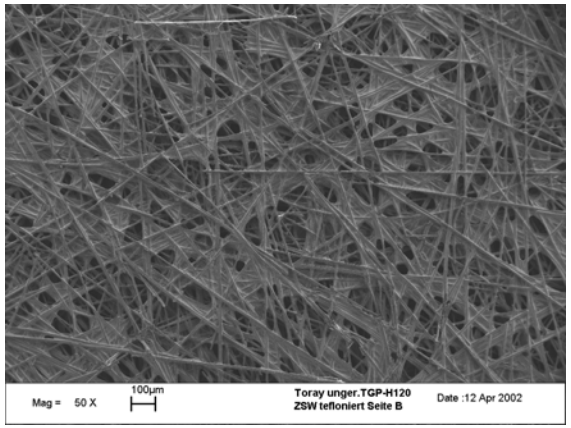
Components of PEMFC

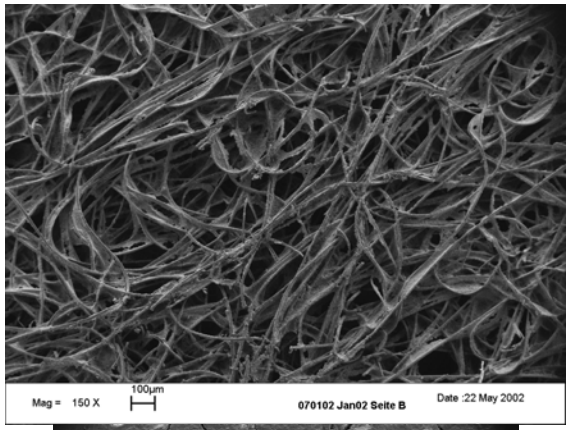


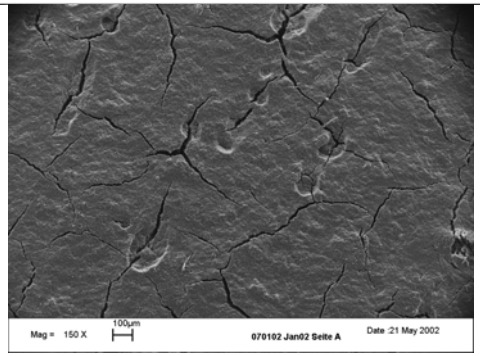


10 cm

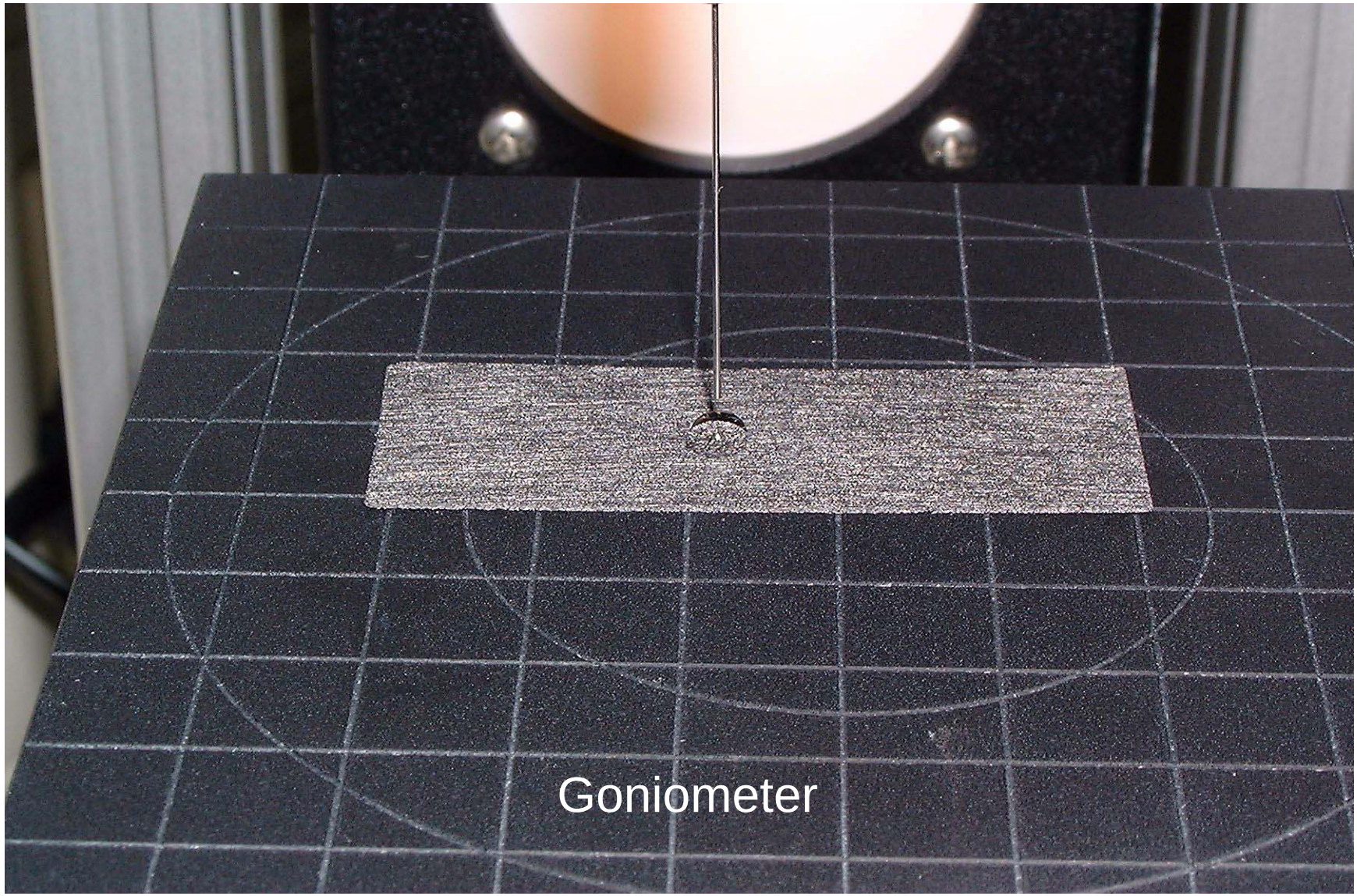




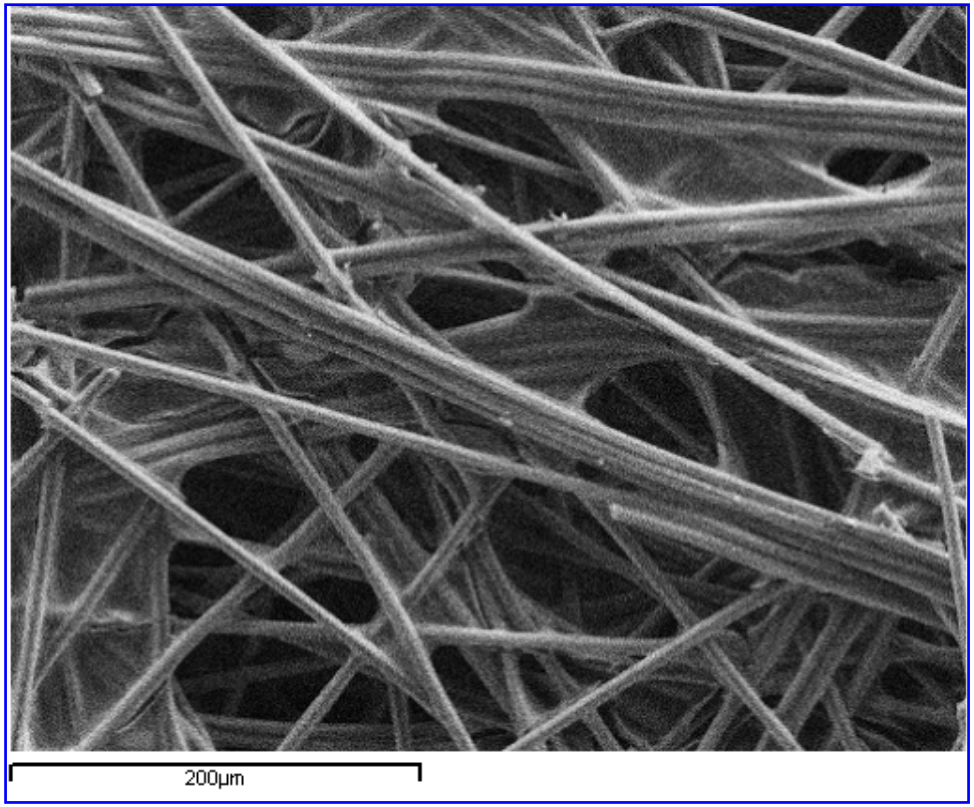


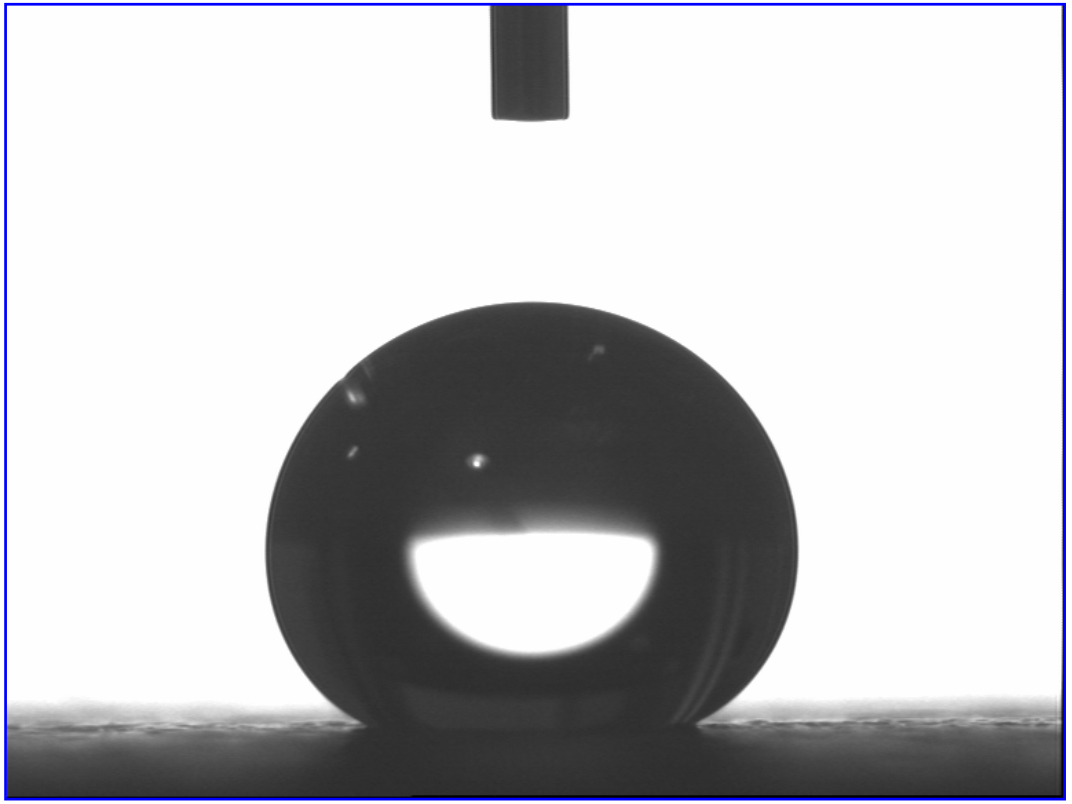


Measurement of contact angle



Contact angle of water on the DGL





GDL: TGP-H-120 with 14 % PTFE 15 µl


Thank you for your attention !