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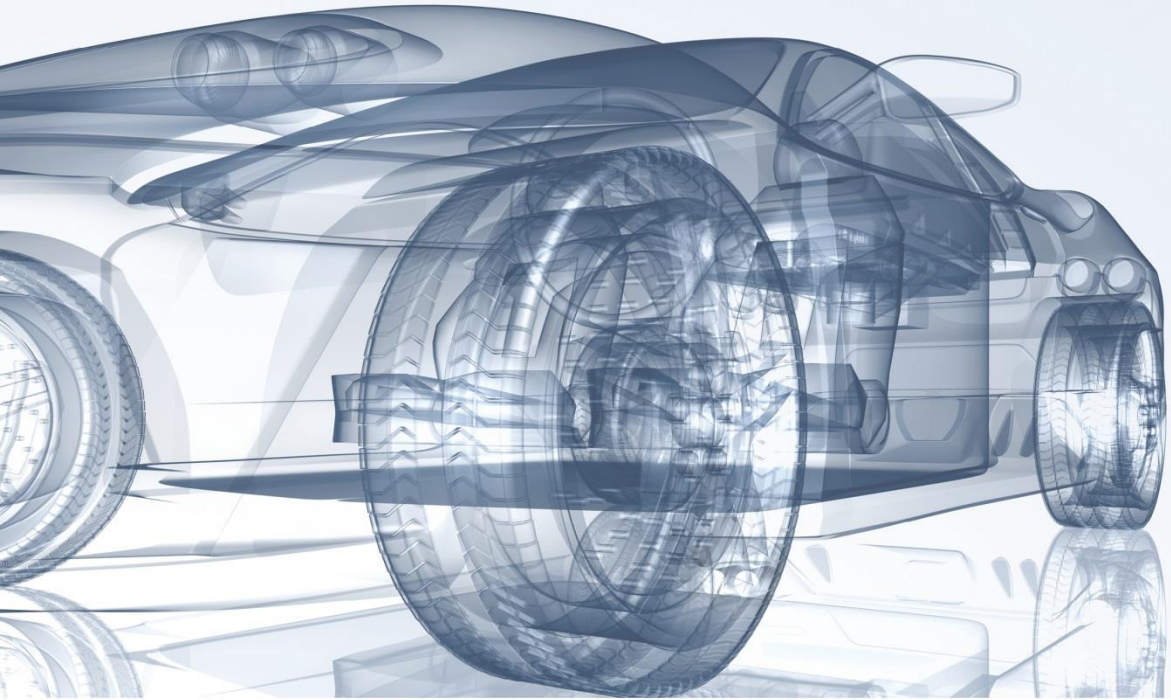

The 30th International
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Contamination Control for Fuel Cell Systems

Stefan Diersch, Dr. Michael Harenbrock

Contamination Control for Fuel Cell Systems
Agenda

- Company introduction
- Electric Mobility - challenges and opportunities
- Clean Air for Fuel Cell stacks
  - Laboratory investigation
  - Real-life contamination
  - Material development
  - Filter design
- Clean Coolant for Fuel Cell stacks
  - Particle filter
  - Ion exchange filter
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MANN+HUMMEL
at a glance

Top **50** patent applicants

Employees **20,000**

Founded in **1941**

70 locations

Sales in billion € **4**

24 filters per second

Over **3,000** patents

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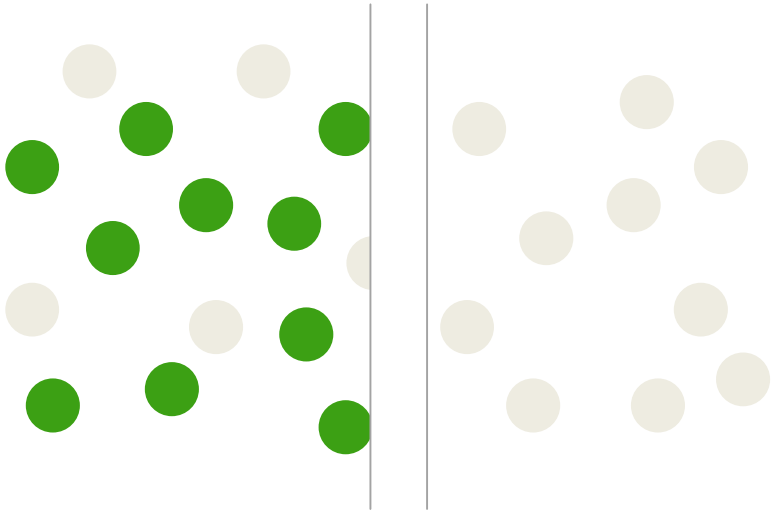
Electric Mobility - challenges and opportunities

Filtration = Separating the harmful from the useful



The **harmful**: e. g. gases, water, particles, ions

The **useful**: e. g. air & liquid for cooling, cabin & cathode air

Electric Mobility - challenges and opportunities

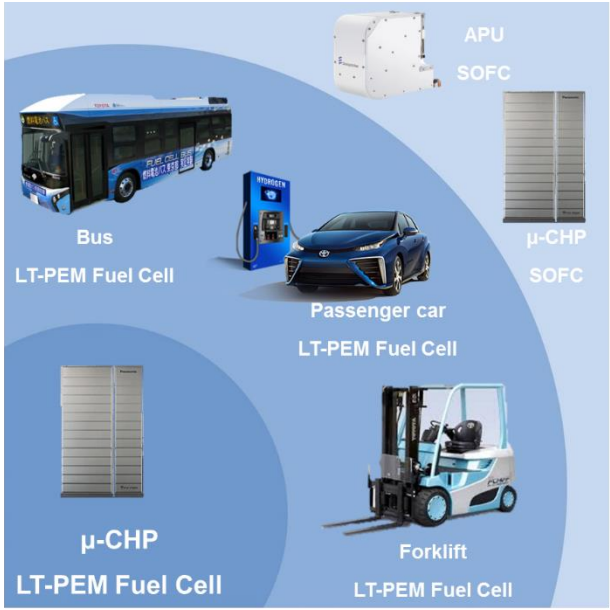
Strategic approach

The MANN+HUMMEL concept:

- Develop **products for Early Markets**
- **Transfer** products to other applications
- **Adapt** products for e. g. SOFC technology

Requirements:

- In-depth **understanding** of **Contamination Control** in FC Systems
- Development of superior **separation materials**
- **Standardized**, yet flexible **product designs**
- **Simple adaptions** to customer´s requirements



Sources: http://www.toyota.com, http://www.toyotaforklifts.ca, https://panasonic.co.jp, http://www.eberspaecher.com, https://newsroom.toyota.co.jp,

Standardized, scalable market products for system cost reduction

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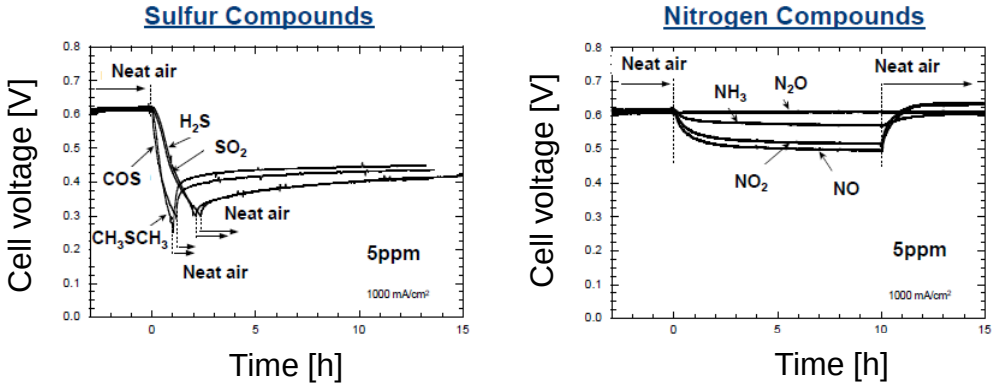
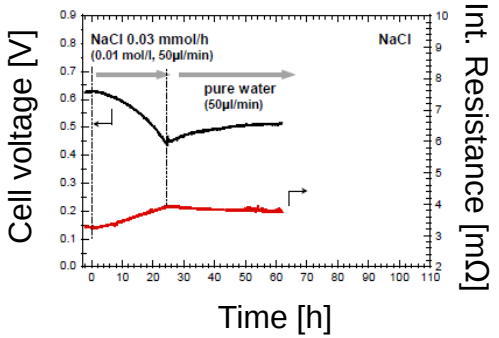
Clean Air for Fuel Cell stacks
Laboratory investigation

- Airborne **contamination decreases** the power output and **lifetime** of LT PEM FC Systems

- Typical contaminations are:
  - **Particles**
    - NaCl, $CaCl_2$,…
  - **Gases**
    - Sulfur-containing, e. g. SO_2, H_2S
    - Nitrogen-containing, e. g. NH_3, NO_x

- To achieve FC stack cost reduction, the **catalyst concentration** has to be **minimized**



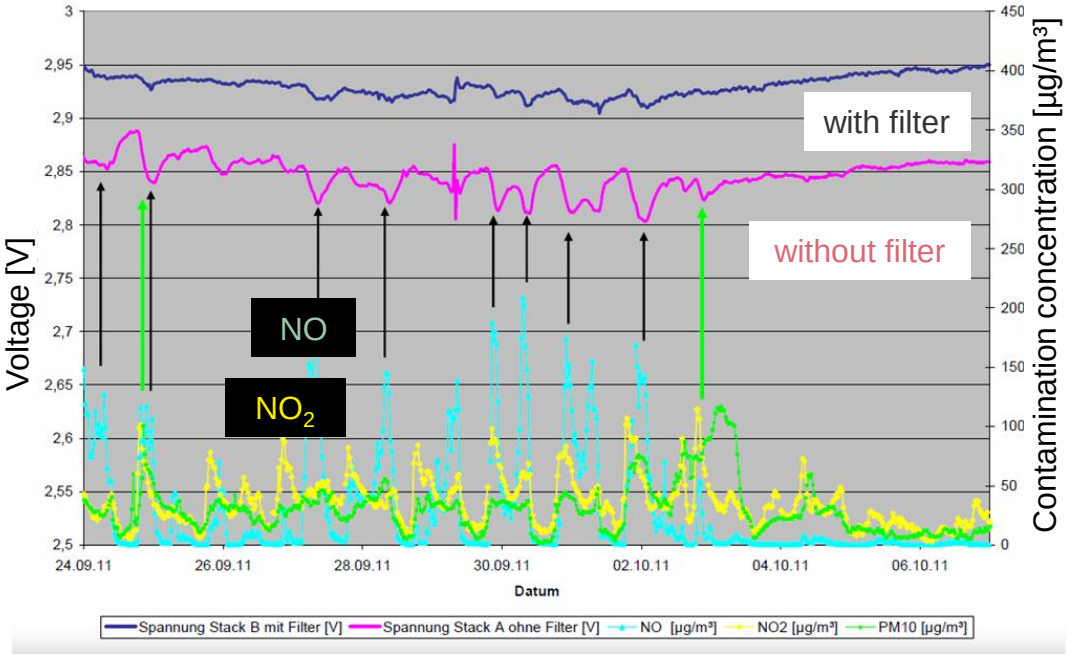


Daichi Imamura, *Influence of impurities in the air on Fuel Cell Performance* International Workshop on the Effects of Fuel & Air Quality to the Performance of Fuel Cells Sep 9th-11th 2009, Berlin Germany

Need for improved protection of the catalyst

Clean Air for Fuel Cell stacks

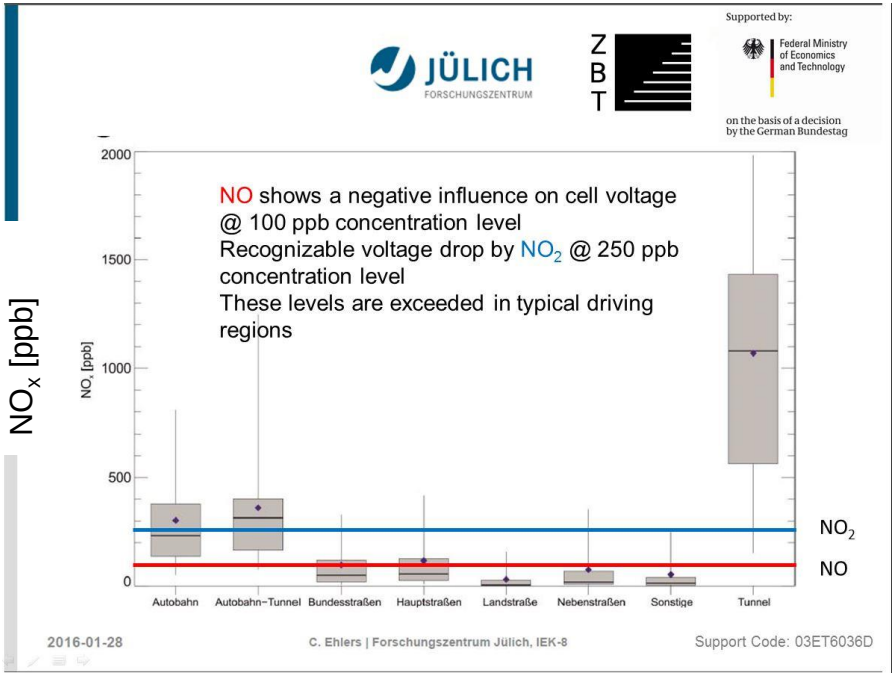
Real-life contamination - Proof-of-Concept (ZBT tests)



Verification of lab resuts with MANN+HUMMEL Cathode Air Filter

Clean Air for Fuel Cell stacks

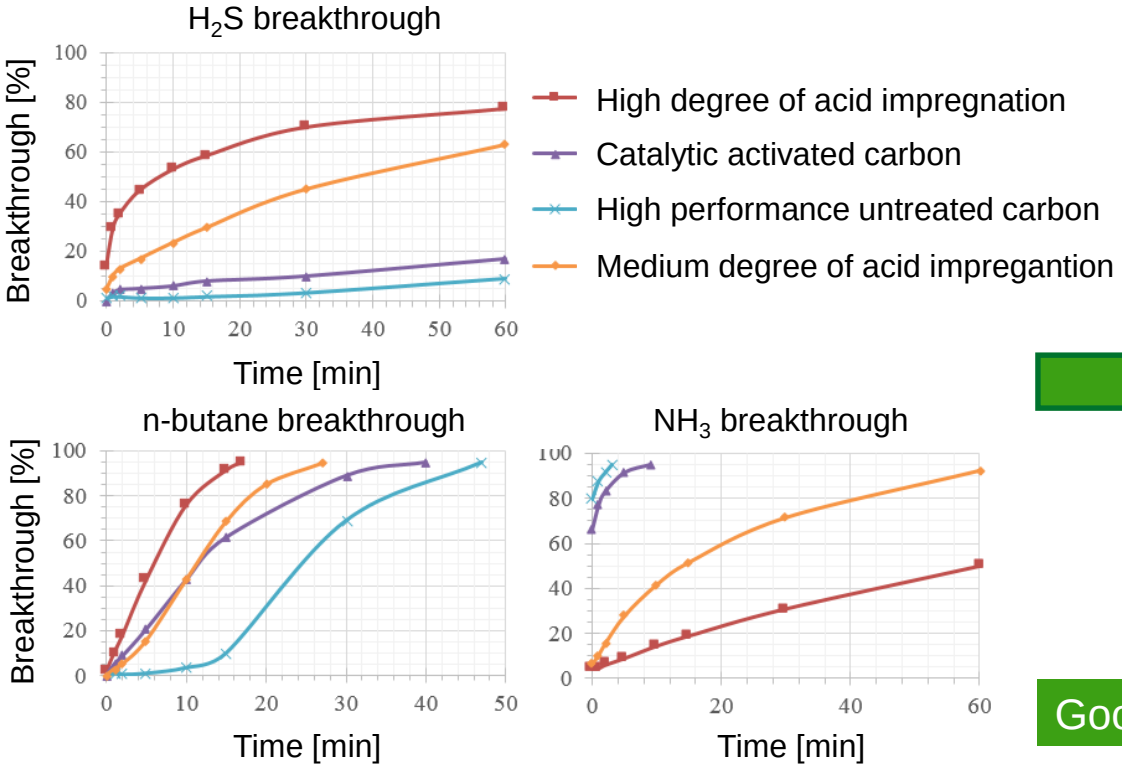
Real-life contamination - (MobiLab, FZ Jülich)

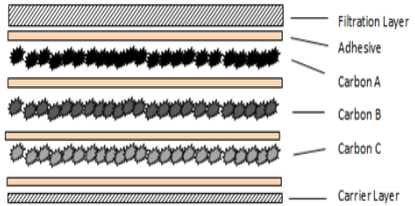


By permission of ZBT Duisburg and FZ Jülich

Critical concentrations are exceeded in Germany, too!

Clean Air for Fuel Cell stacks
Materials - Activated Carbon development



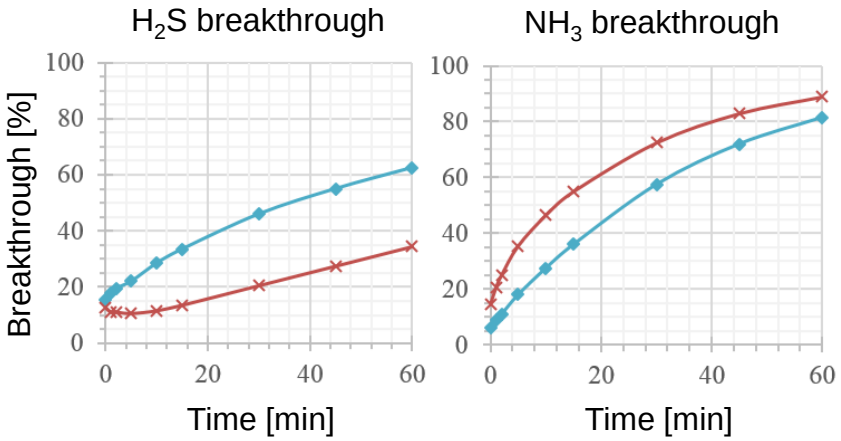


Good possibility for tailored products

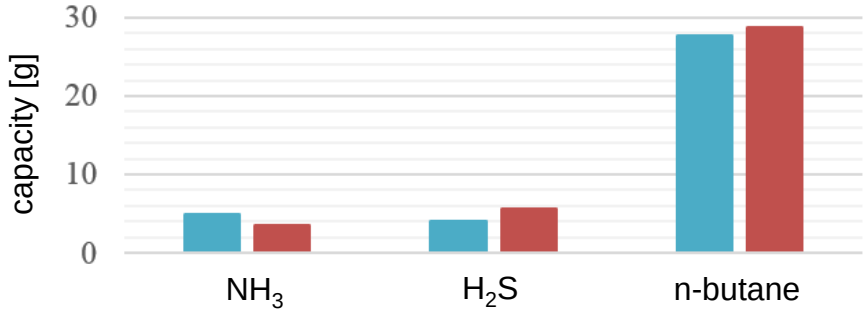
Clean Air for Fuel Cell stacks

Media development – Adsorbent materials

Breakthrough curves



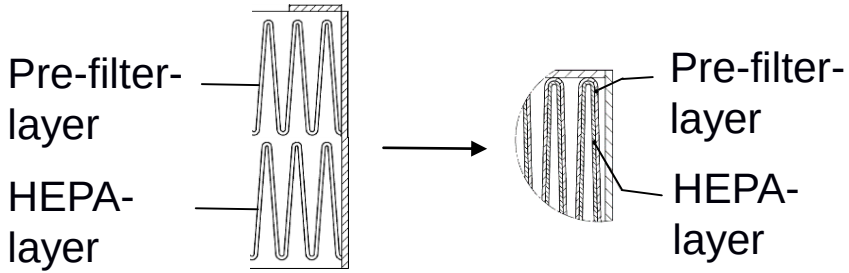
Adsorption capacities



New field experience drives product innovation

Clean Air for Fuel Cell stacks
Media development – particle filter media

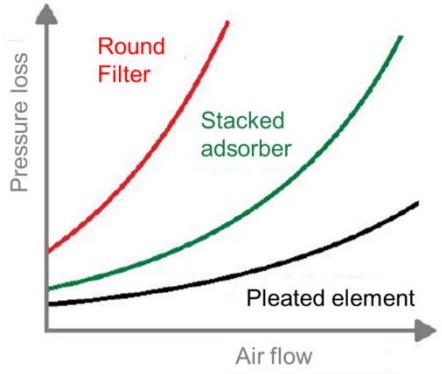
- Particle filter media types in **different separation classes** are available (ISO16890 / EN1822)
- The **disadvantage** is a potentially fast **media clogging**
- A **double Layer Bellow** combines an high efficient with a pre filter bellow

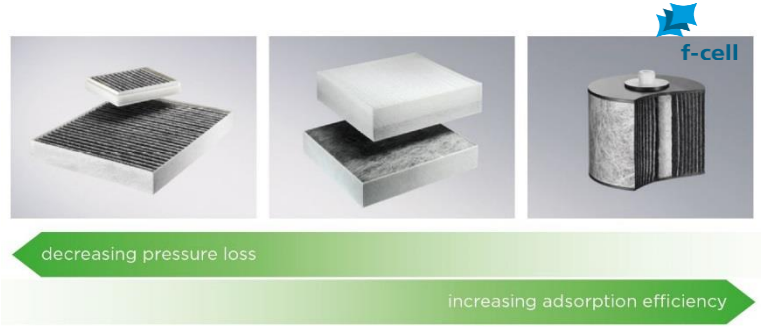


High efficiency and lifetime in a small mounting space

Clean Air for Fuel Cell stacks
Filter Designs

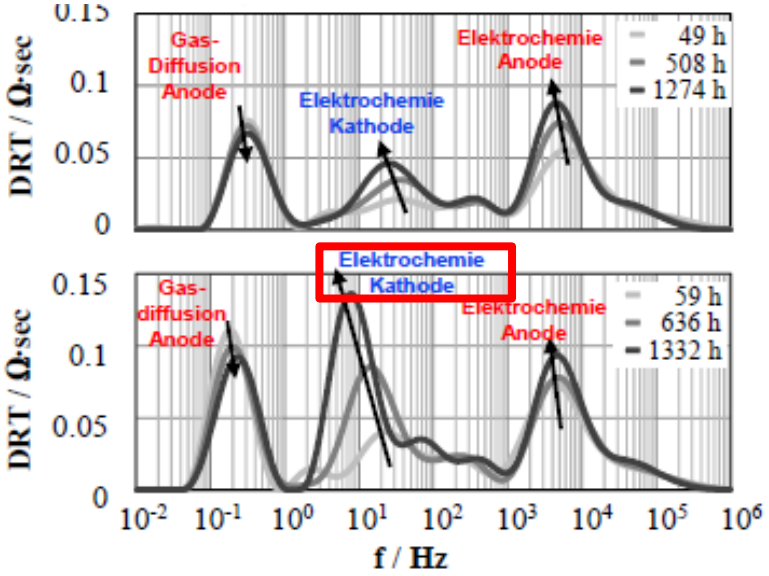
- Selection of **element design** based on application requirements
- **Existing** production **processes** are applied
- Round filter element design with **cost benefits**
  - Low tooling costs for variants
  - Use without a housing possible
  - Easy adaption of adsorption performance

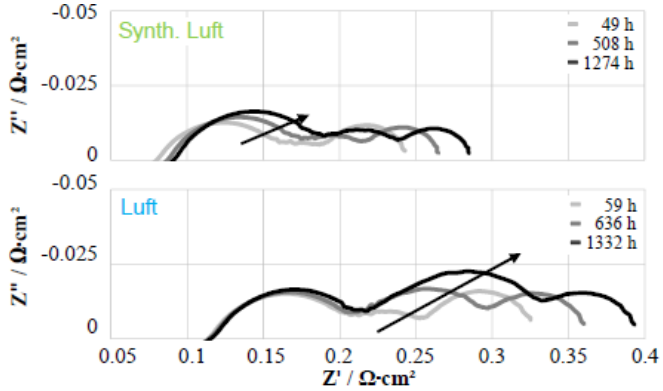




Clean Air for Fuel Cell stacks
From LT-PEM to SOFC (KIT-IAM results)

- Cathode ageing, increase of resistivity: **SO_2 critical**





- T = 750°C
- OCV
- a: CO / CO_2 (50:50), 250 sccm
- c: synth. Luft, Luft, 250 sccm
- LSCF Thick Film Cath. ($La_{0.58}Sr_{0.4}Co_{0.2}Fe_{0.8}O_{3-d}$)

Product transfer from LT-PEM to SOFC

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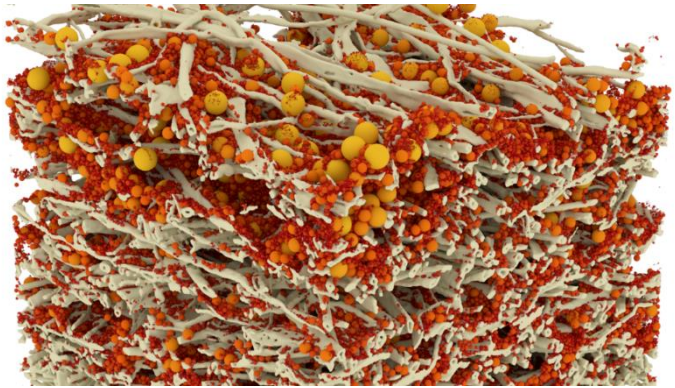
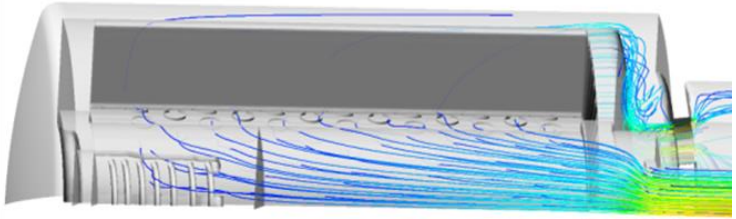
Clean Coolant for Fuel Cell stacks
Particle Filter - The product concept

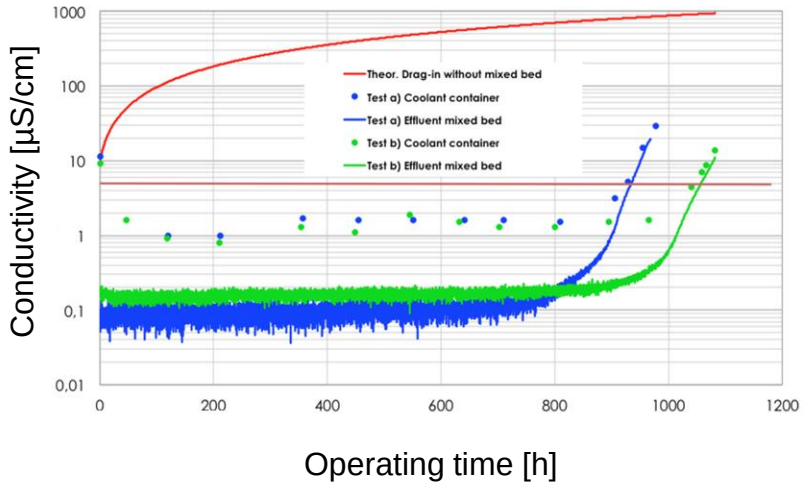
- **Removal of particles** from the coolant with **fiber-based filtration media**
- **Separation of splinters** which could pass simple filter meshes by applying **3D fiber structure**
- Reduces the risk of
  - **Blocking of cooling channels**
  - **Wear** in the **pump**
- **Flow simulations** for **optimized pressure drop**
- Special requirements for **material selection** in the fuel cell coolant loop





Clean Coolant for Fuel Cell stacks
Ion Exchange Filter - The need for removal of impurities

- Ion contamination leads to **electric shorts**
- Coolant contamination (examples):
  - Al from **metal surfaces**
  - Fe from **contacts, corrosion,…**
  - Si from **MEA**
  - **Leaching** from plastics
- Challenges for IEX Technology in FCEV:
  - Operating temperatures -30°C - +90°C
  - **No** significant **degradation** by heat and freezing
  - **No de-mixing** of the resins



Clean Coolant for Fuel Cell stacks
Ion Exchange Filter - The product portfolio

- Resins with **high temperature stability**
- Supporting **grid structure** to
  - Avoid de-mixing
  - Optimize flow
- 2 diameters x 2 lengths = **4 products**
- **Flexible mounting** positions
- **Standard connectors**

Product capacity and volume			
		Diameter	
		2“	3“
Length	6“	200 meq 300 ml	490 meq 700 ml
	10“	330 meq 500 ml	820 meq 1150 ml

Highly standardized product portfolio for 200 – 820 meq. capacity

Ion Exchange Filters for DMFC
From Clean Coolant to Clean Methanol/Water Mix

Table 4 – Contaminations found in the eluate.

Material	Cations (ICP-MS)	Anions (IC)	Organics (FT-ICR)
MB-1	–	–	–
Amberlite IRN 150	–	–	–
Amberlite MB 3	–	–	–
Amberjet UP 6150[a]	–	–	Organic contaminations detected
i2m	–	–	–
UCW 9966[a]	–	–	Organic contaminations detected
MB 434	Ba: 1.46/µg l^{-1}	–	–
UCW 3700[a]	–	–	Organic contaminations detected
MB 59	Mg: 10.5/µg l^{-1}	–	–
Dowex Marathon MR-3-L	–	–	–
Amberlite MB-20-L	–	–	–

[a] These materials contain organic contaminations. For this reason, they can not be used for the DMFC application.

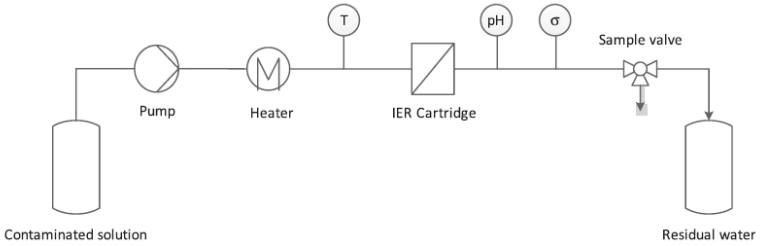


Fig. 2 – Test bench.

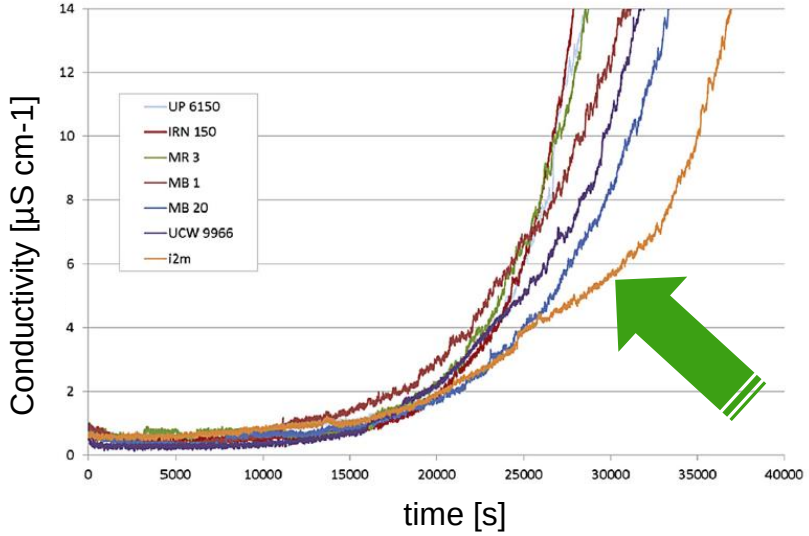


Fig. 4 – Conductivity vs. Time for different IER materials.

Schulze Lohoff A, et al., Extending the lifetime of direct methanol fuel cell systems to more than 20,000 h by applying ion exchange resins, International Journal of Hydrogen Energy (2016), http://dx.doi.org/10.1016/j.ijhydene.2016.06.207

Product transfer from LT-PEM to DMFC

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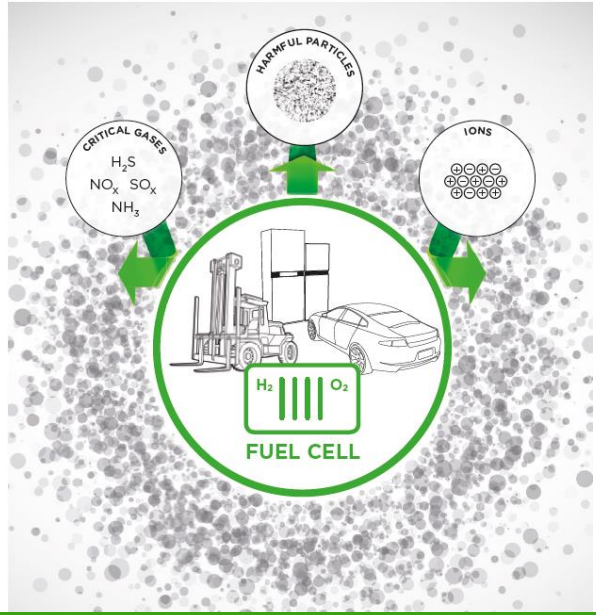
Summary
Best-value products for Contamination

- MANN+HUMMEL transfers **competence in Filtration & Separation** to Fuel Cell applications
- **Market product development** based on
  - Knowledge of real-life contamination
  - The effect on the system lifetime
- **Standardized**, yet flexible **product portfolio** to achieve **cost savings**



MANN+HUMMEL: your partner for Fuel Cell protection

Thank You!


MANN+HUMMEL
Stefan Diersch
Research & Development Fuel Cell Filters
MANN+HUMMEL
Innenraumfilter GmbH & Co. KG
Kulmbacher Str. 12
95502 Himmelkron
Germany
Phone +49 9273 9656 - 495
Fax +49 9273 9656 - 11 495
stefan.diersch@mann-hummel.com
www.mann-hummel.com
MANN+HUMMEL
Dr. Harenbrock, Michael
Senior Expert Electric Mobility
MANN+HUMMEL GMBH
Schwieberdinger Str. 126
D-71636 Ludwigsburg
Germany
Phone +49 7141 98-2242
Fax +49 7141 98-18 2242
Mobile +49 171 4926113
michael.harenbrock@mann-hummel.com
www.mann-hummel.com