# ADVANCED CHARACTERIZATION OF FUEL CELL STACKS

photo Joscha Feuerstein

Stefan Keller

Fraunhofer Institute for Solar Energy Systems ISE

Hannover, April 4th 2019

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# Business Area Hydrogen Technologies at Fraunhofer ISE

Department Thermochemical Processes (Dr. Achim Schaadt)

- Synthesis of $H_2$ and $CO_2$ to liquid energy carriers/fuels or chemicals (PtL)
- Catalytic evaporation of liquid hydrocarbons
- Life cycle assessment in the field of hydrogen technologies

Department Chemical Energy Storage (Dr. Tom Smolinka)

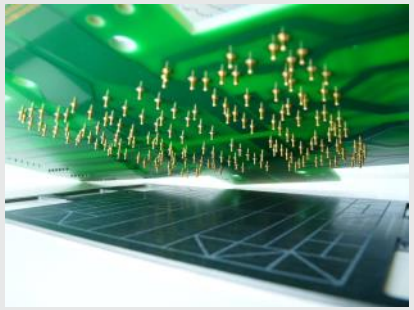
- Hydrogen generation by PEM water electrolysis
- Energy storage in H2 systems and redox flow batteries
- Power-to-Gas: Interconnection of the power and gas grid

Department Fuel Cell Systems (Ulf Groos)

- Single cell and spatially resolved characterization of fuel cells and stacks
- Production research for membrane electrode assemblies and gas diffusion layers
- System technology: balance of plant and operating strategies

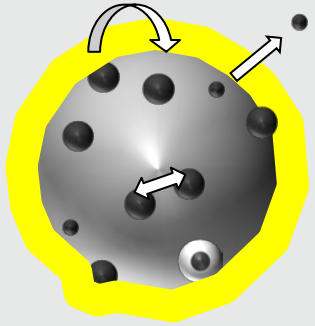
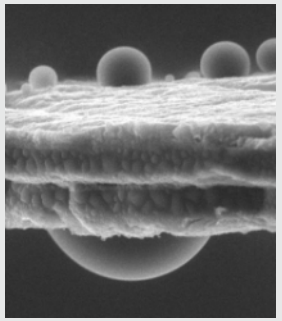
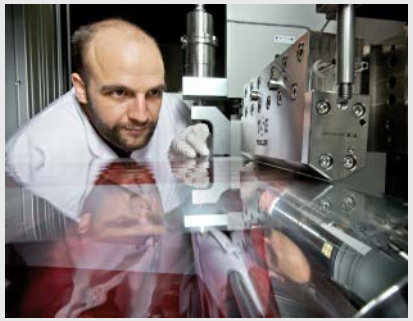
# We are assisting fuel cell industry for over 25 years

- performance characterization
- life-time analysis
- local phenomena
- contamination effects
- climate tests
- testing balance-of-plant components





# Our equipment for characterization of fuel cell stacks

## Test bench, climate chamber and stack impedance system

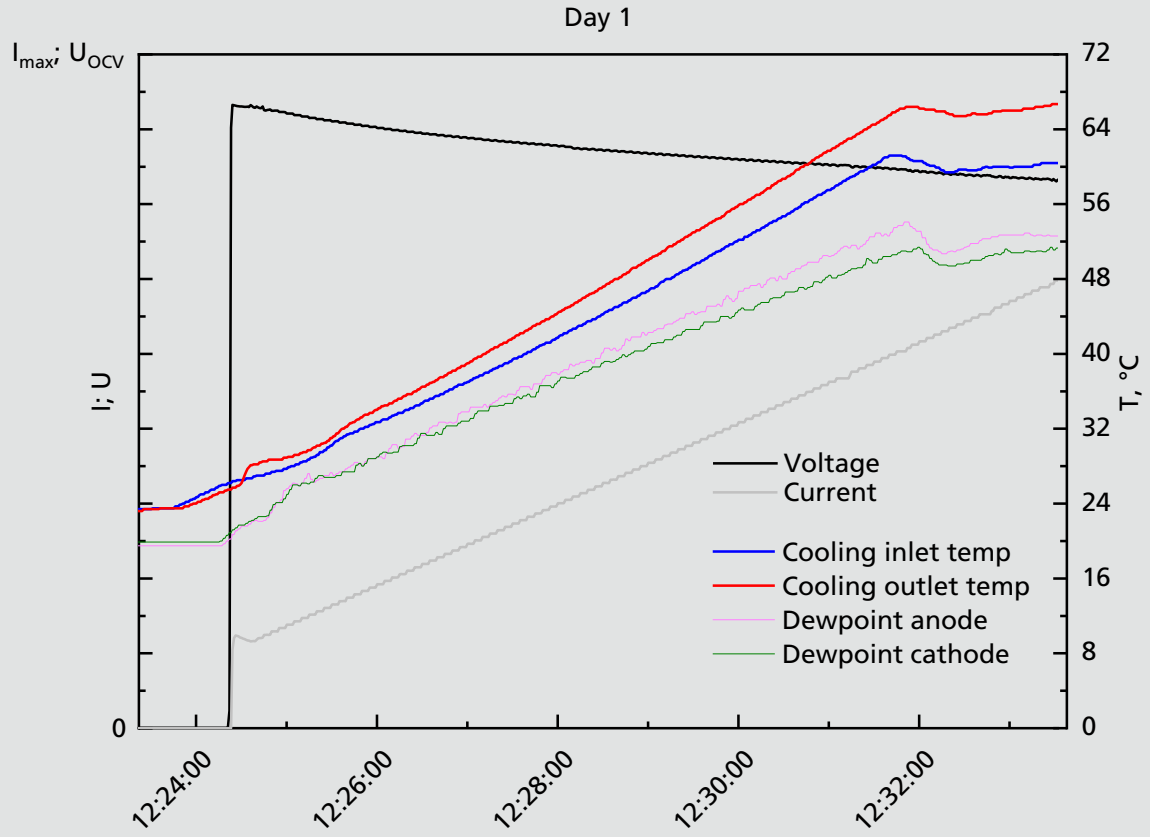
photo Joscha Feuerstein

Test bench

- 20 kW | 1 000 A | 150 cell voltage channels
- Gas supply: Anode 0.5 – 400 Nl/min; Cathode 1.5 – 1 600 Nl/min
- Gas temperature: 30 – 100 °C
- Humidification: Dew point 20 – 90 °C scrubber humidifier with dry bypass
- Cooling: 40 kW cooling / 6 kW heating | max. 90 °C | 3,4 – 73 l/min
- Pressure control: 1.1 - 4 bara
- Automated operation 24 / 7 possible

# Our equipment for characterization of fuel cell stacks

## Fully automatic operation guarantees reproducible results




Comparison of the start up procedure between two days of an endurance test





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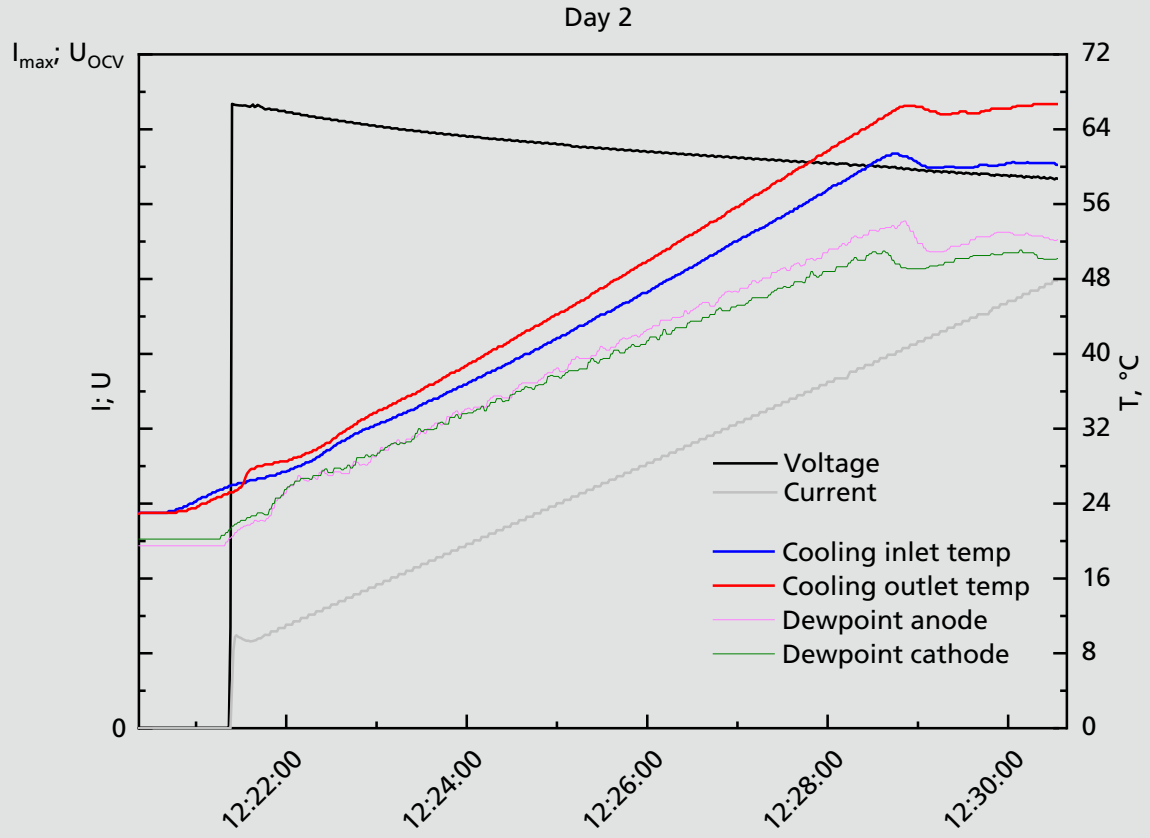


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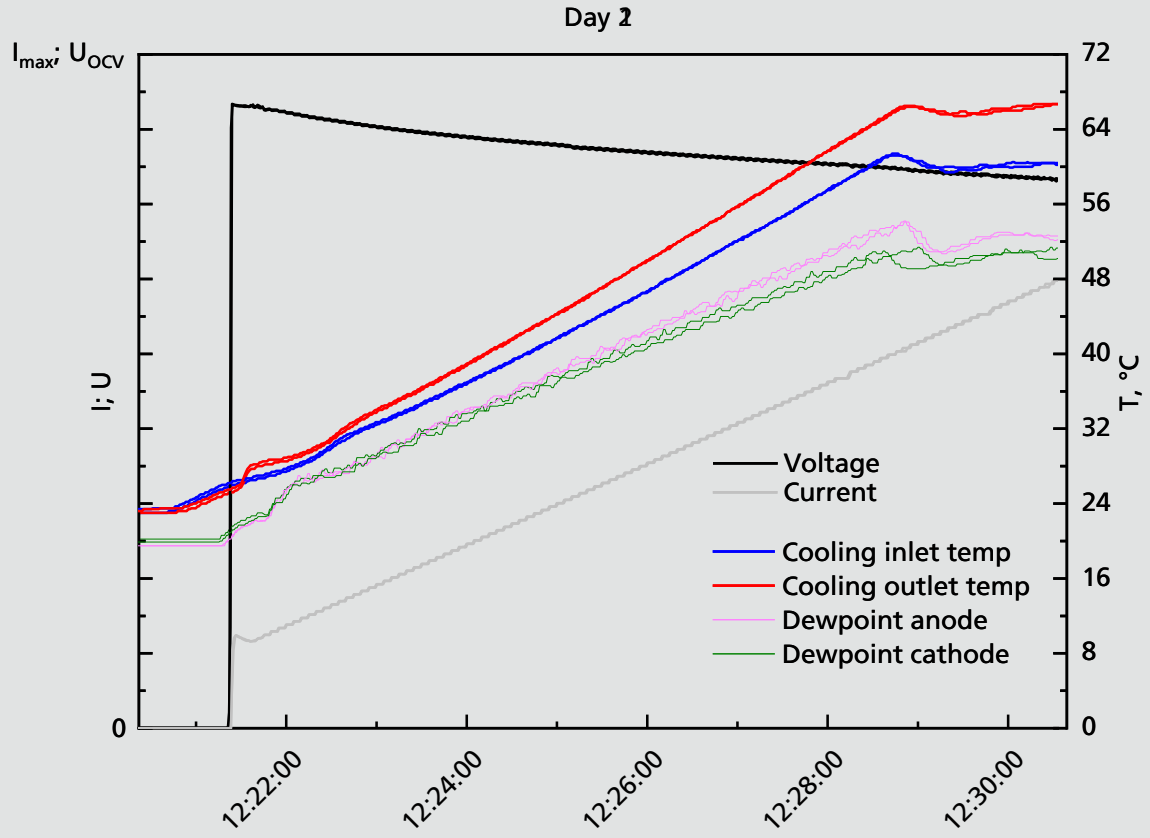


Comparison of the start up procedure between two days of an endurance test

- Virtually no difference





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# Our equipment for characterization of fuel cell stacks

## Test bench, climate chamber and stack impedance system

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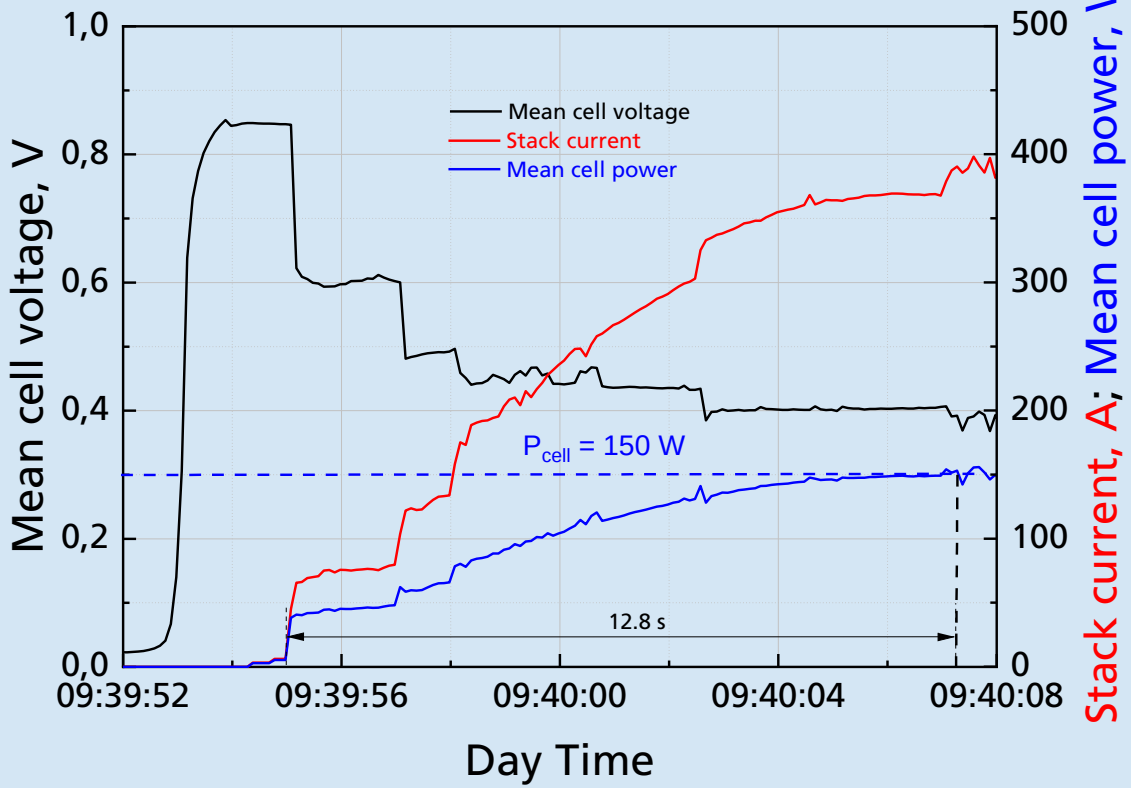
Climate chamber

- Temperature range from -50 °C to +80 °C
  -20 °C @ 10 $kW_{th}$
- Temp. tolerance: ± 1 K
- Humidity range from
  +5 % r.H. to +95 % r.H. @ temperatures above +10 °C
- Humidity tolerance: ± 3 %
- Internal dimensions 2 x 2 x 2 m³
- Supply of conditioned air up to 2 000 m³ / h
- Gas supply provided by test bench

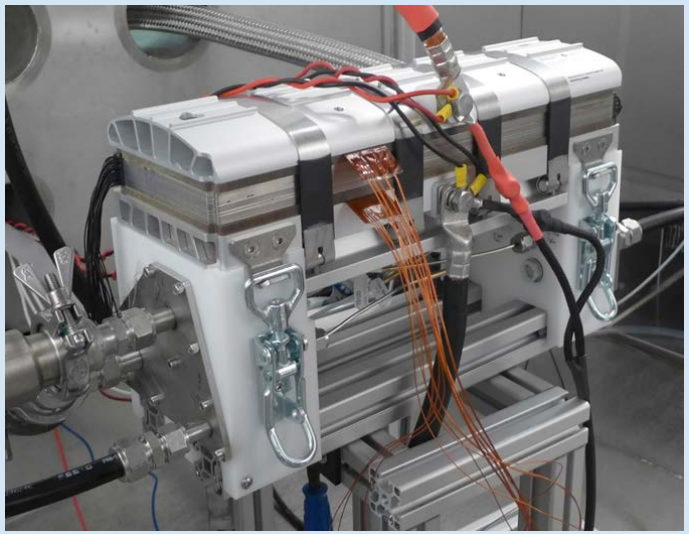
# Our equipment for characterization of fuel cell stacks

## Freeze start capability of 20 cell short stack proven




Autostack CORE Evolution 2

- Less than 13 s to 50 % nominal power @ -20 °C







FUEL CELLS AND HYDROGEN JOINT UNDERTAKING GA: 325335

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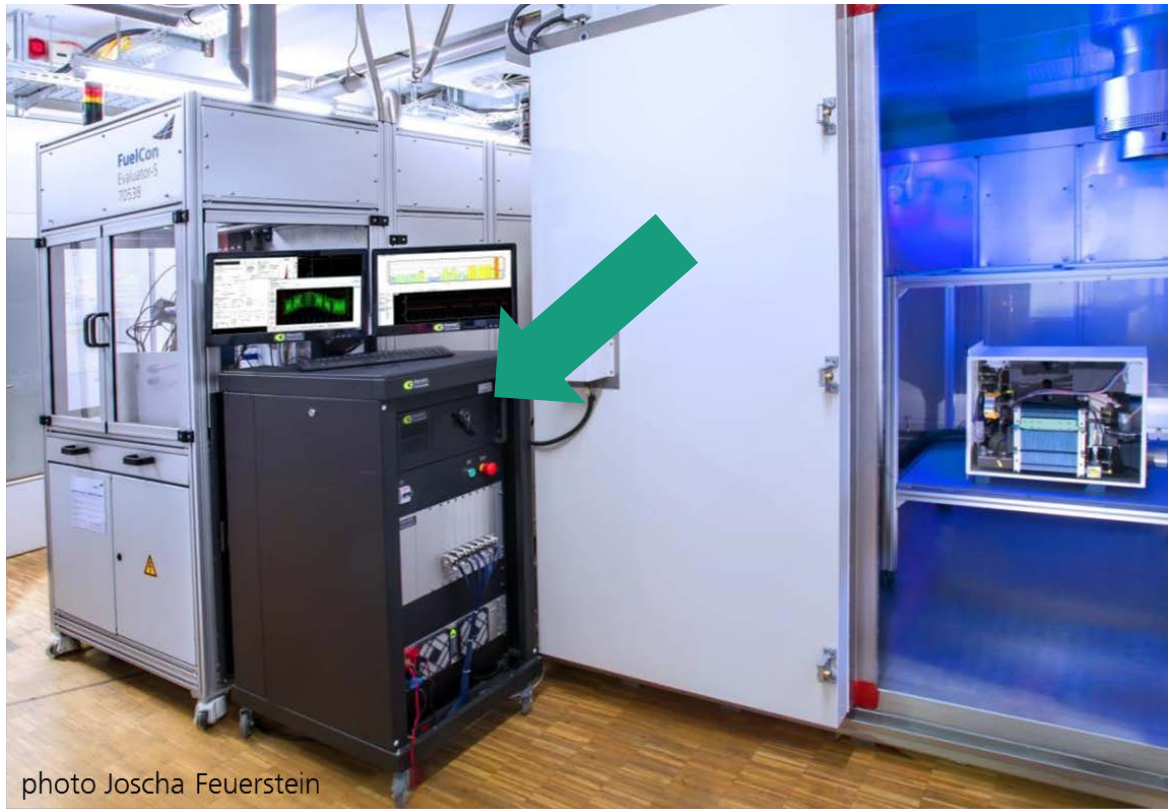


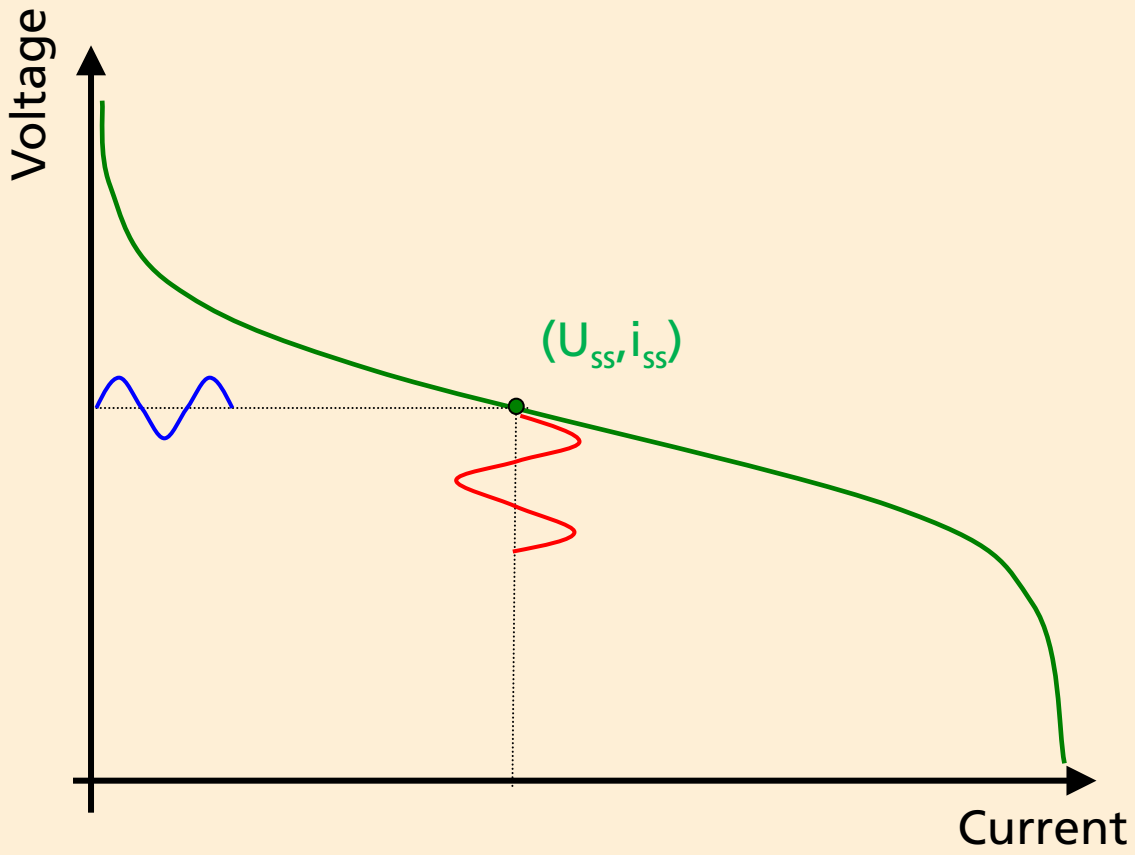
photo Joscha Feuerstein

Stack impedance system

- 150 V / 25 A
- 28 channels with synchronized measurement
- Frequency range 20 kHz – 0.01 Hz
- Pre-amplification to increase SNR
- Use of low inductance + low capacitive cabling

# Our equipment for characterization of fuel cell stacks

## Impedance data provides additional information about your stack




- Steady-state point $(U_{ss},i_{ss})$
- Superimposed by small perturbation $i(t)=i_{ss}+i_{AC}\ \sin(2\pi\ f\ t)$
- Frequency dependent response $U(t)=U_{ss}+U_{AC}\ \sin(2\pi\ f\ t+\varphi)$

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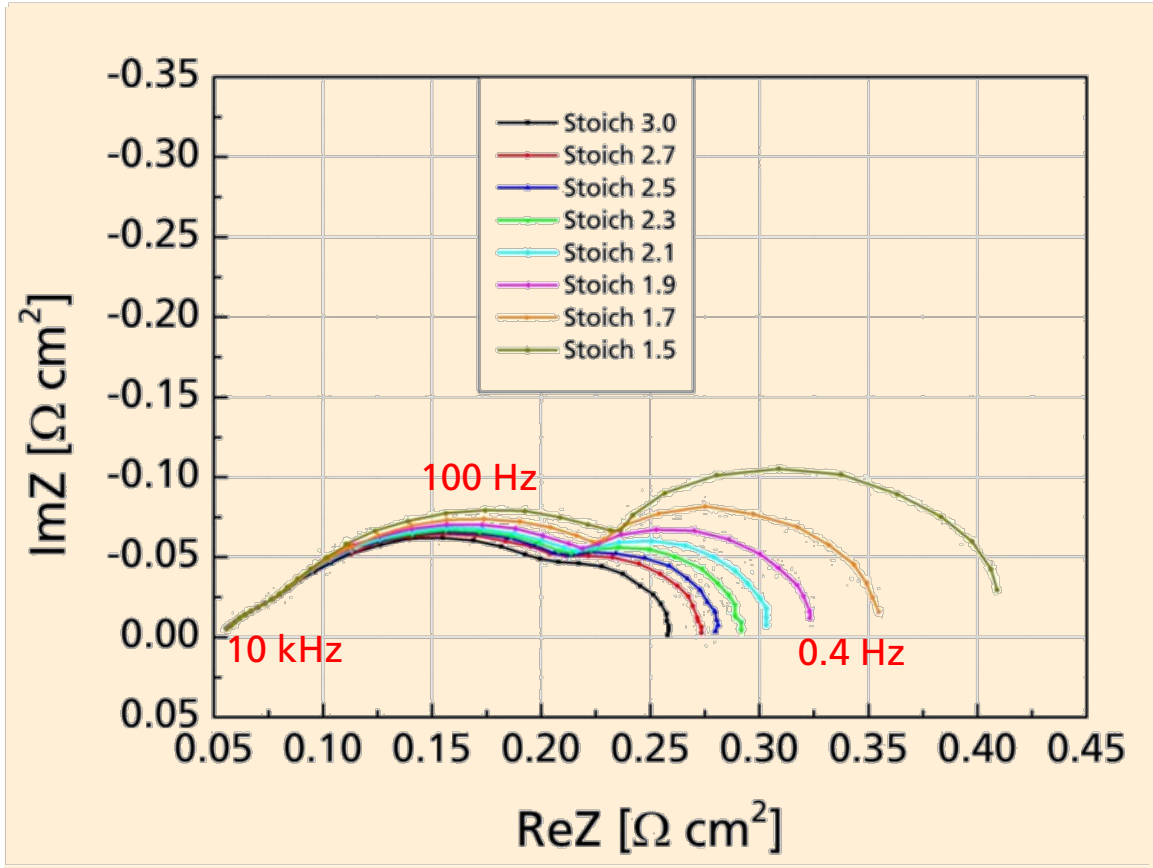


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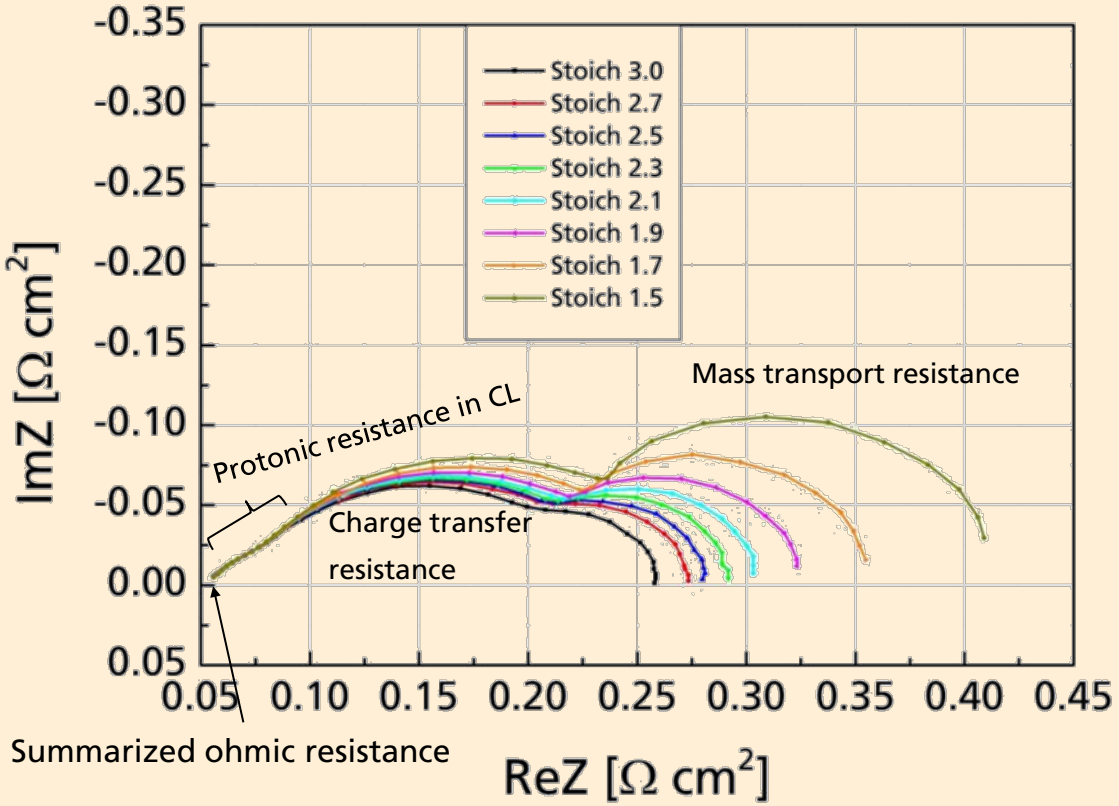


- Different frequencies address different processes
- Better separation of the various loss mechanisms
- In situ procedure

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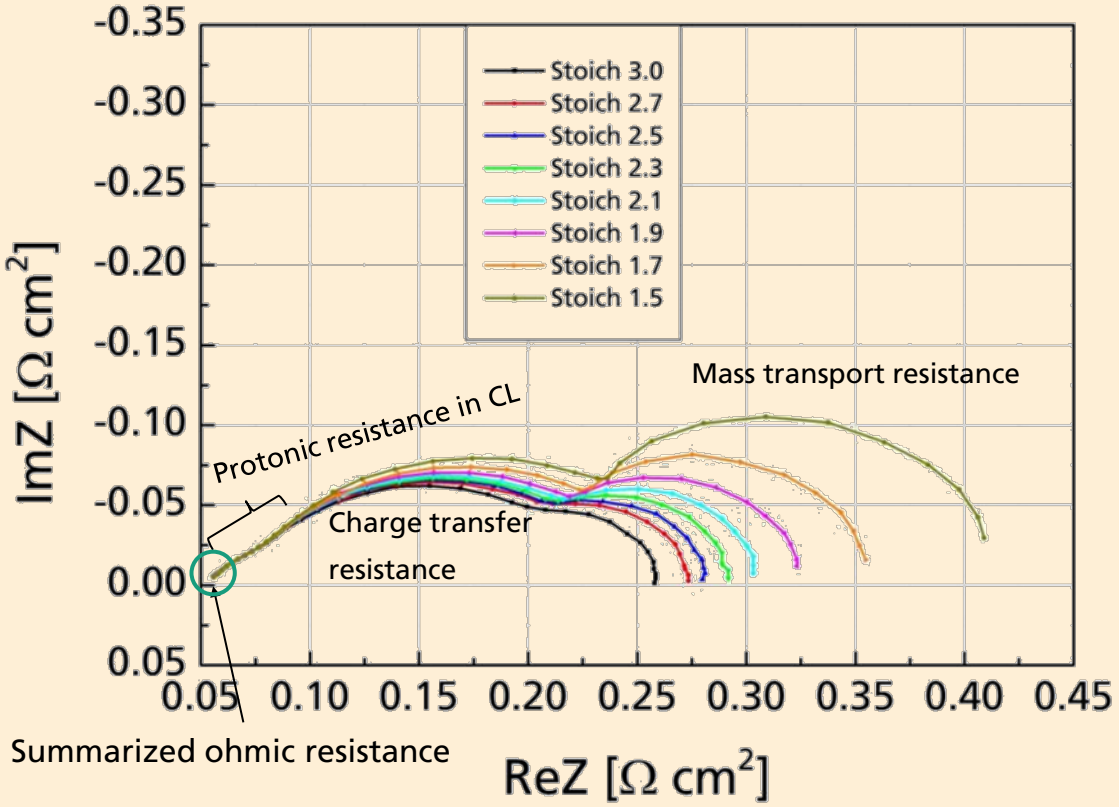


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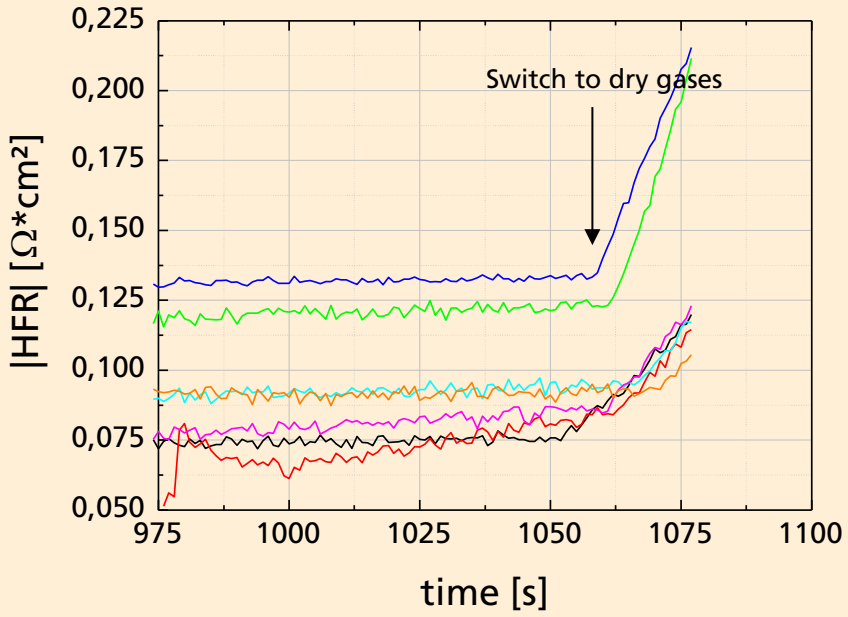




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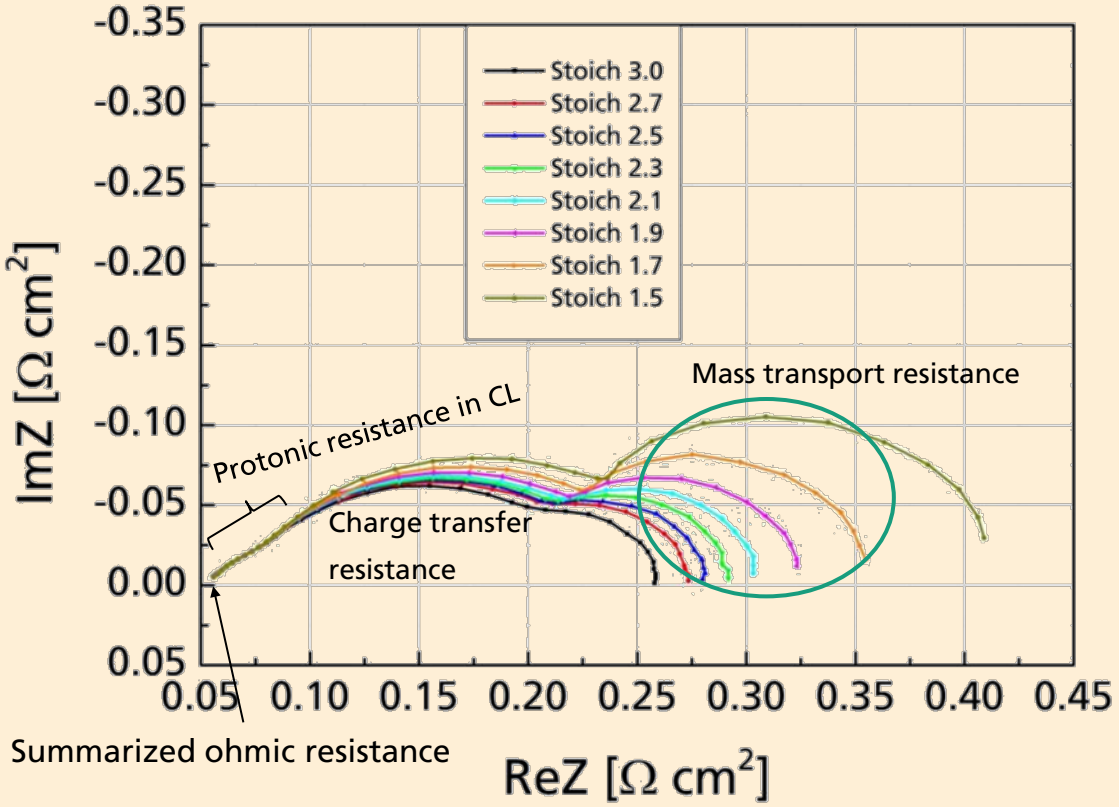


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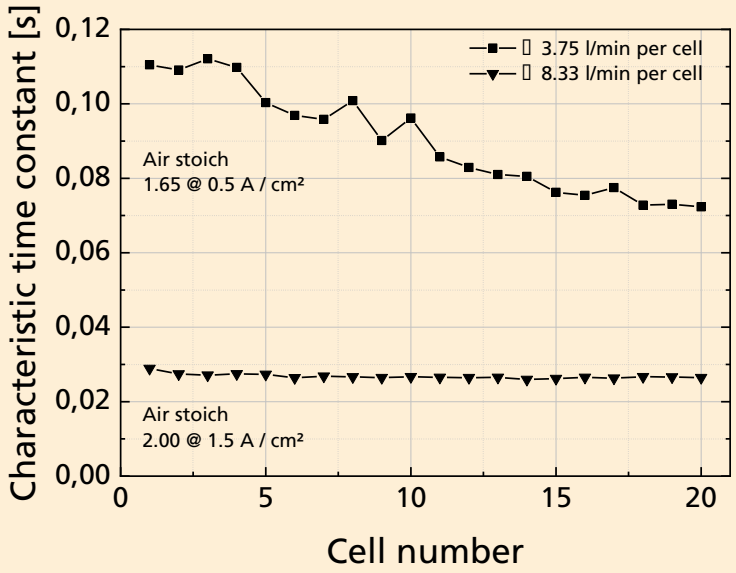




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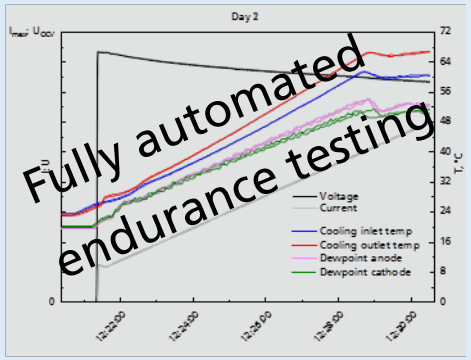
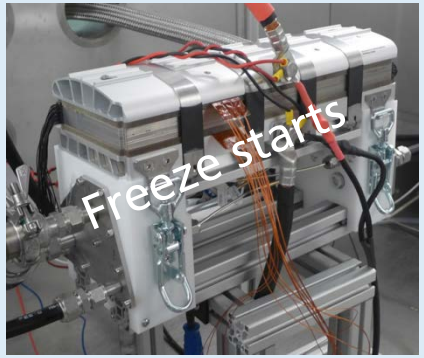
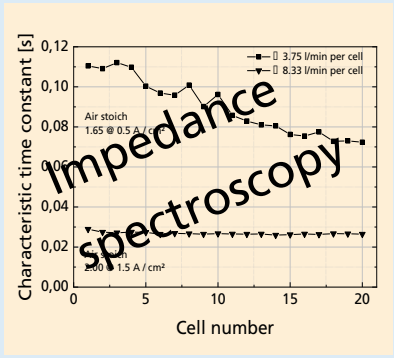
# Join us at our booth C58 for a good cup of Freiburg roasted coffee!

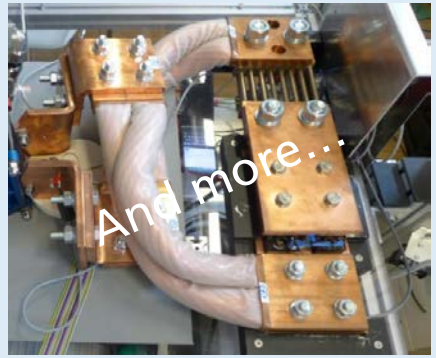
Follow our talks @ Technical Forum also in YouTube channel of H2FC fair:

- Tuesday, April 2, 14:00 | Max Julius Hadrich:  Pathways for Power-to-Liquid fuels and chemicals
- Wednesday, April 3, 13:00 | Ulf Groos: Characterization of fuel cell MEAs
- Thursday, April 4, 16:00 | Thomas Jungmann: Testing of fuel cell bop components in H2 atmosphere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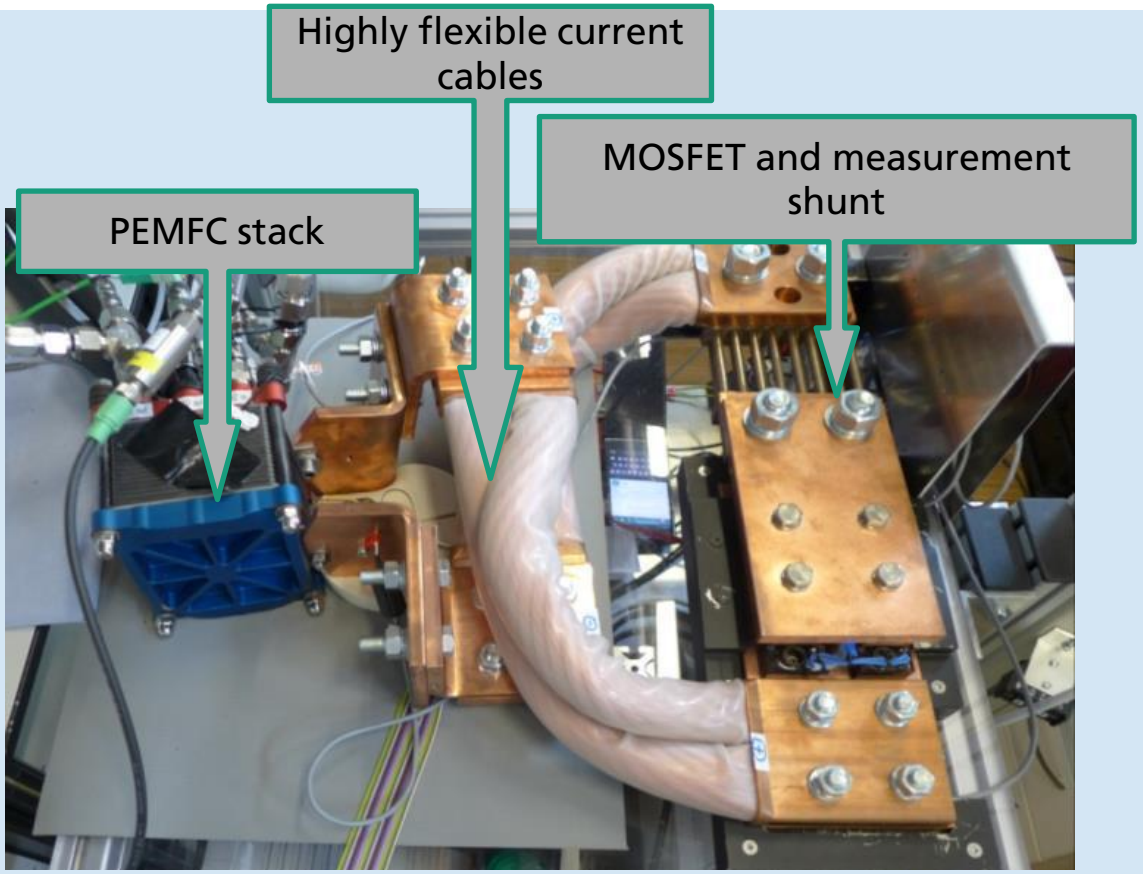
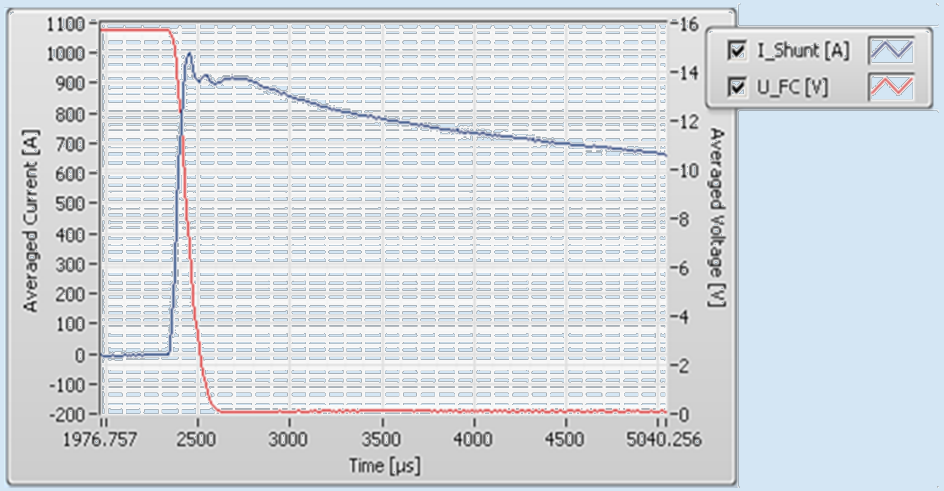
# Short circuit and isolation testing of fuel cell stacks

## Ensuring the safety of your device




- MOSFET used for bounce-free circuit switching
- 100 kHz sampling rate
- High cable and bar section (5000 A for 20 ms) to avoid losses
- $OCV_{max}$ 20VDC



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