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Operando and ex-situ investigation of PEMFC degradation

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[†]deceased

DLR

DLR
German Aerospace Center

- Research Institution
- Space Agency
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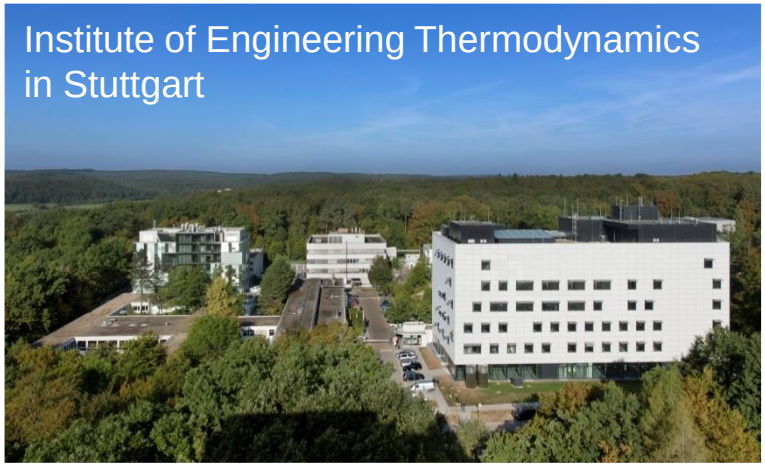
Research Areas

- Aeronautics
- Space
- Transport
- Energy
- Space Agency
- Project Management Agency

Locations and employees

>8000 employees across
40 research institutes and
facilities at 20 sites.

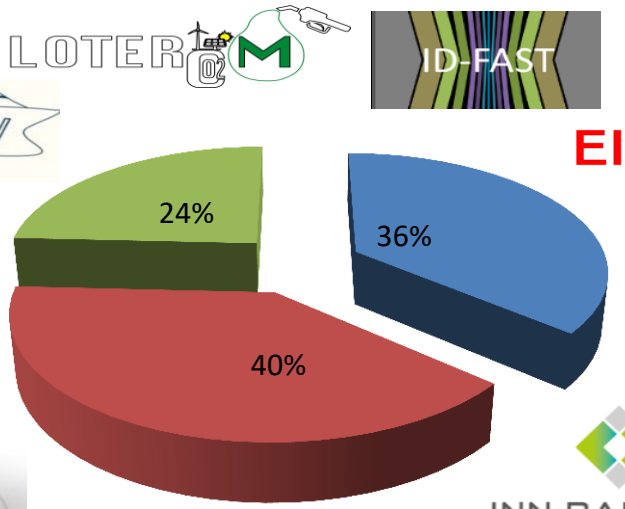
Offices in Brussels,
Paris, Tokyo and Washington.



Low Temperature Polymer Electrolyte Membrane Technology (LTPEM)

Group leaders: Dr. Aldo Gago, Dr. Pawel Gazdzicki

- Durability and System Operation Strategy
- Component Development (Catalyst Layer, MEA, Stack, ...)
- Other topics (CO2 reduction, HTPEM, ...)

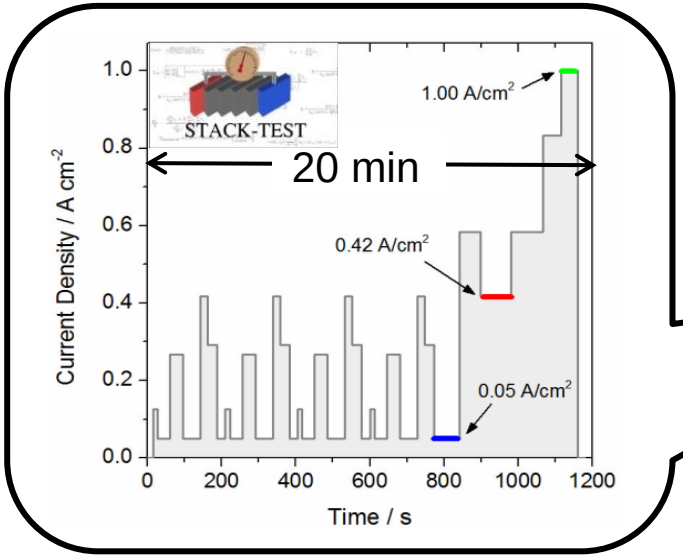


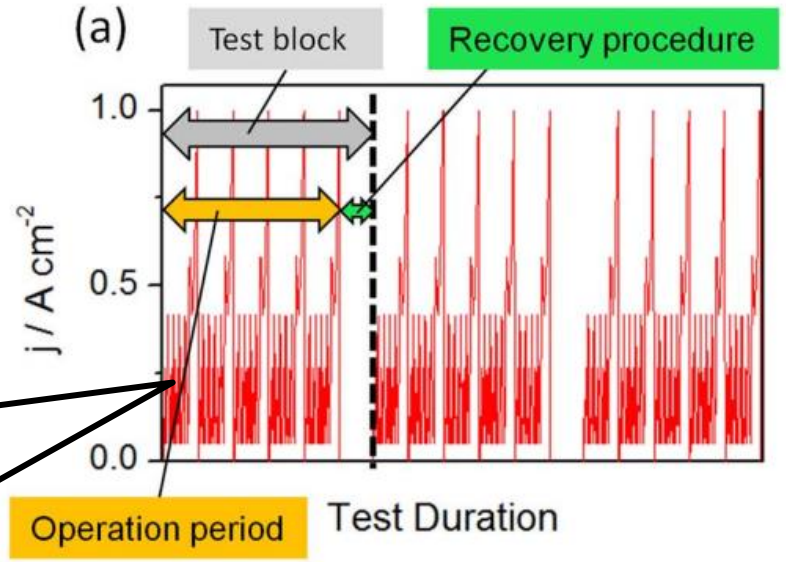
FCPP

FCCP

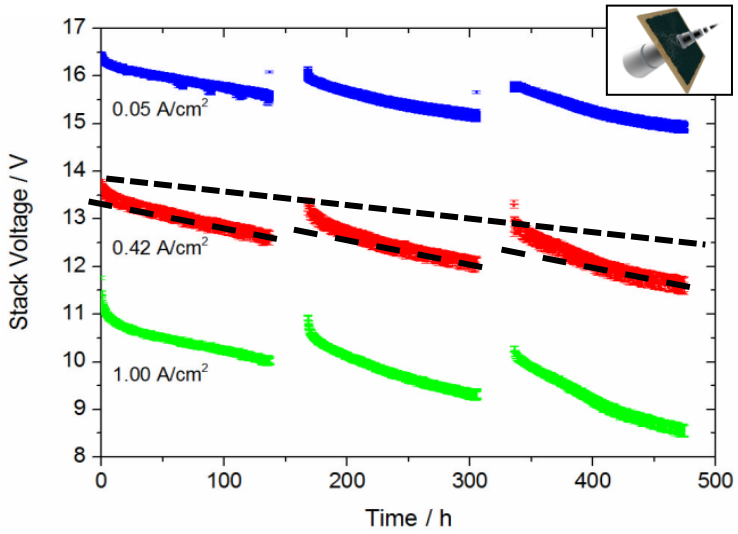
Cooperations

Performance and durability evaluation of PEMFC



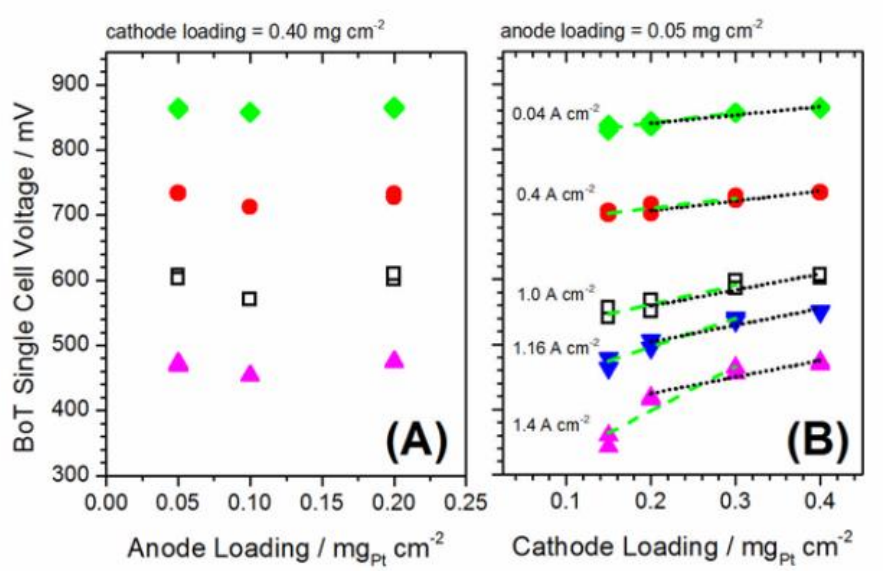


Reversible/Irreversible degradation in dynamic operating conditions

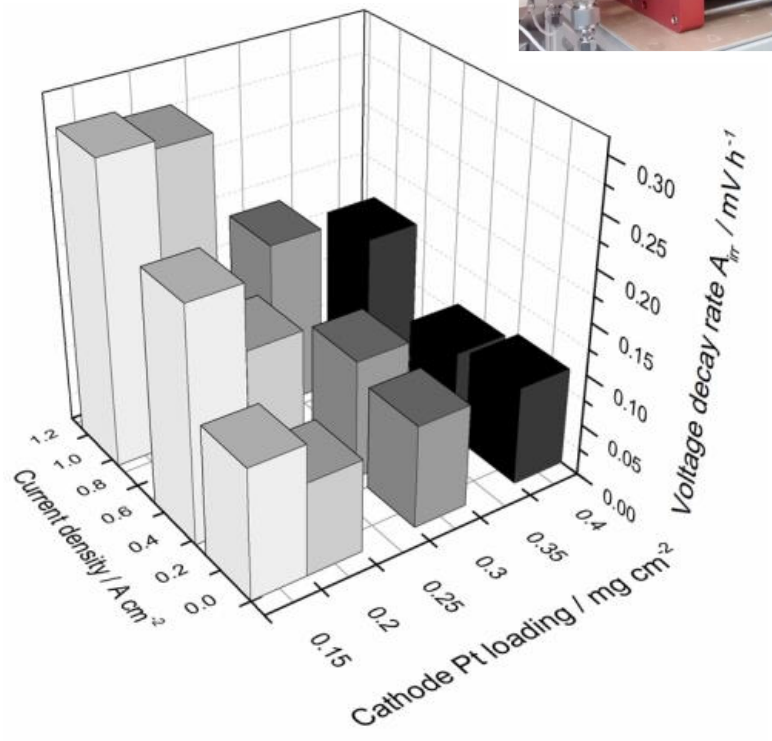


Low Pt loading (Rainbow PEMFC Stack)

Performance



Durability

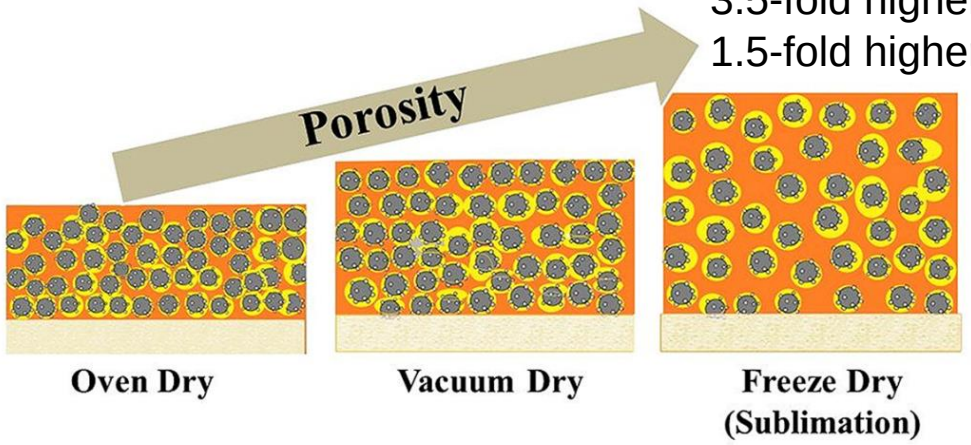


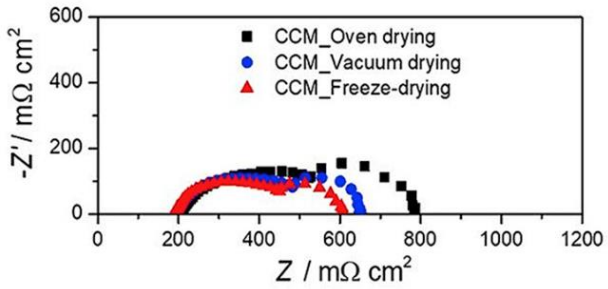
Cathode Pt loading of 0.2 mg cm^{-2} is found to be a threshold value; below this value cell performance and durability drop significantly for current densities >1 A cm^{-2}

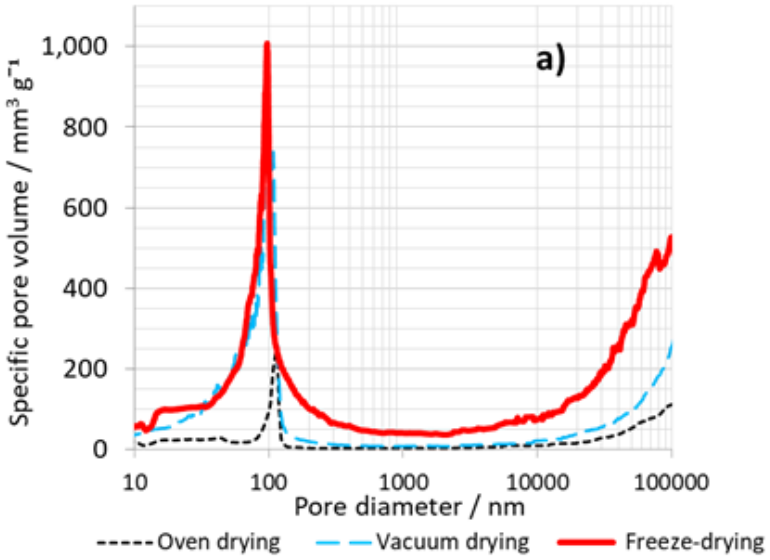
P. Gazdzicki, J. Mitzel, A.M. Dreizler, M. Schulze, K. A. Friedrich, *Fuel Cells*, **18,** 270 (2018).

Improving transport losses at low Pt loading

3.5-fold higher porosity
1.5-fold higher ECSA

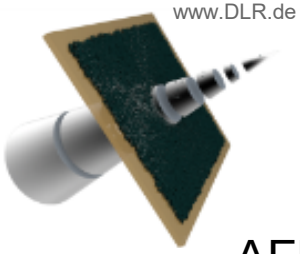






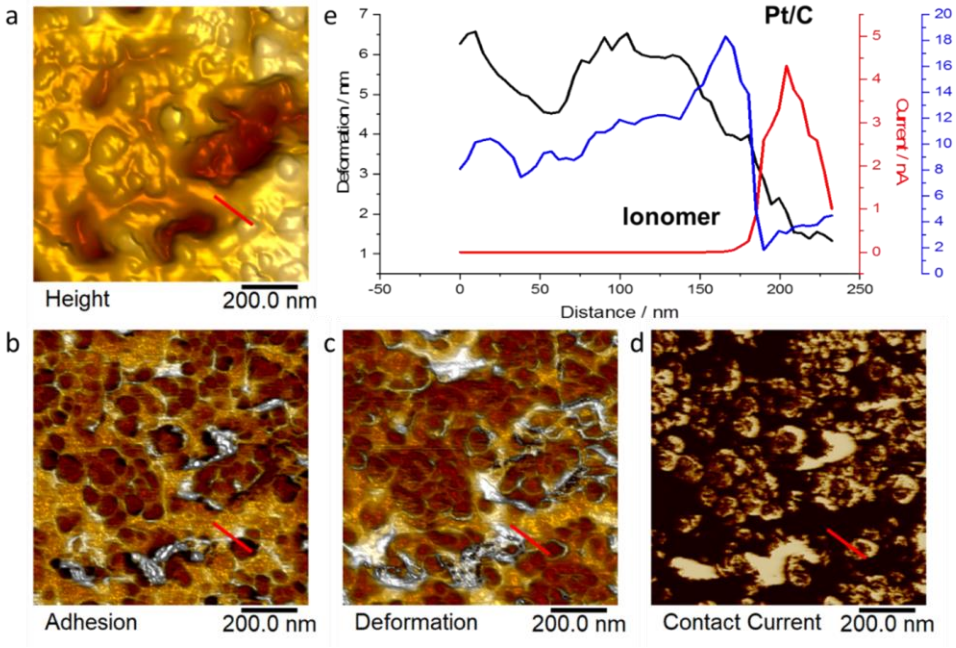
Performance loss at low Pt loading can be reduced by increasing CCL porosity by a freeze-drying step during CCL preparation

K. Talukdar, S. Delgado, T. Lagarteira, P. Gazdzicki, K.A. Friedrich, J. Power Sources, 427, 309 (2019).

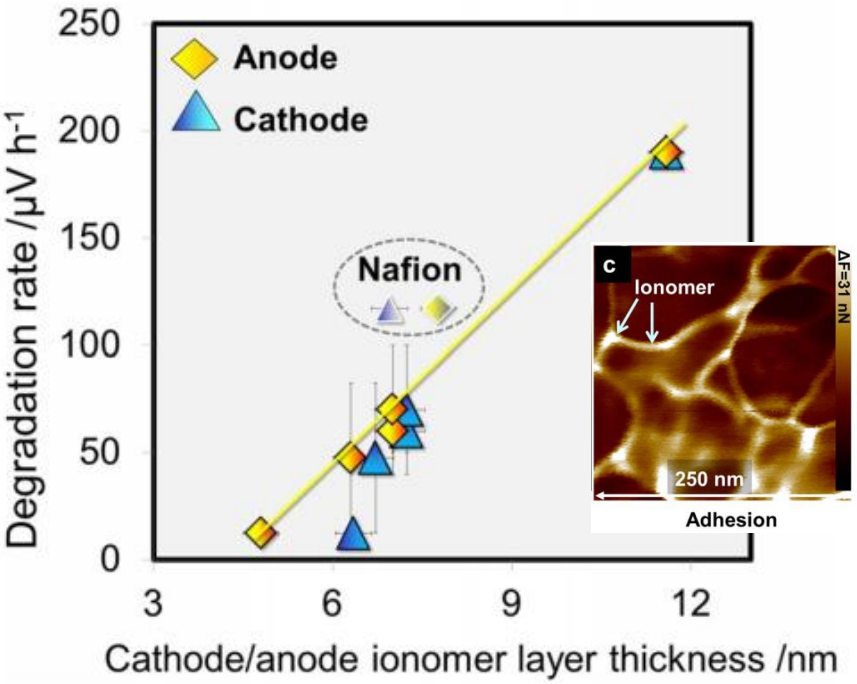


Ionomer degradation in electrodes

AFM surface analysis of CL



AFM cross-section analysis of CL



Ionomer visible due to:

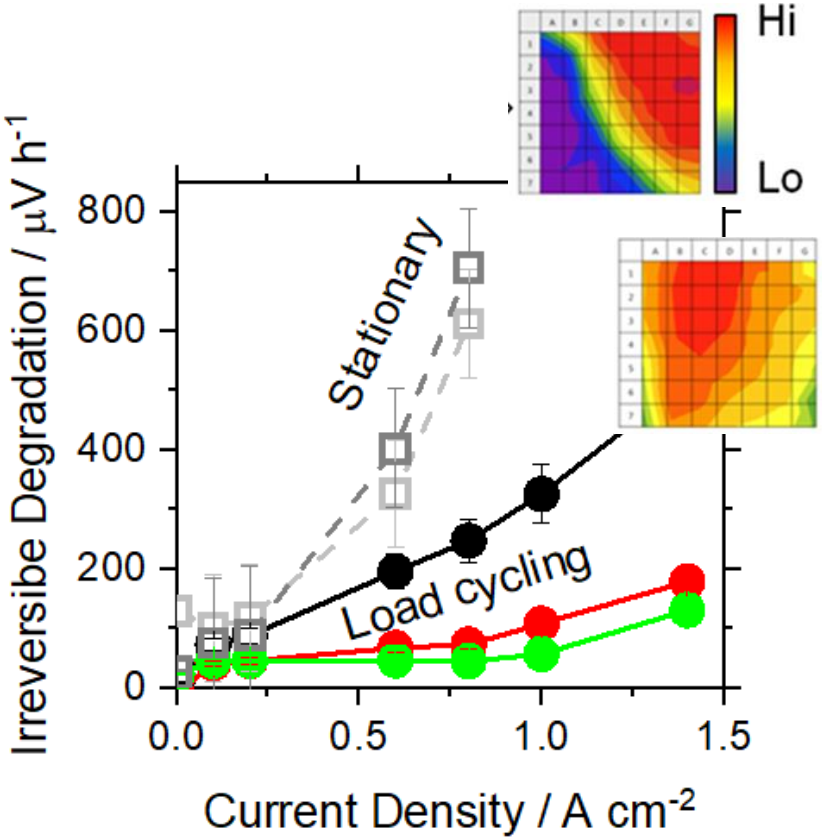
- High deformation and adhesion
- No electronic current

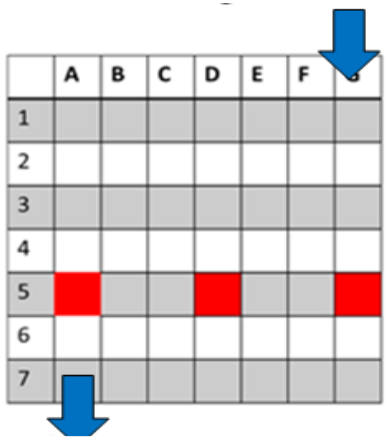
Differently prepared Aquivion-based MEAs:

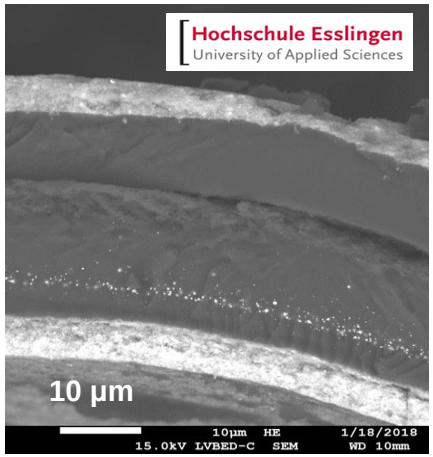
➢ Advantage of thinner ionomer films regarding durability

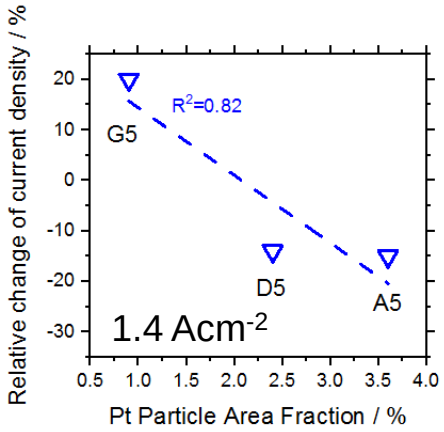
T. Morawietz, M. Handl, C. Oldani, P. Gazdzicki, J. Hunger, F. Wilhelm, J. Blake, K. A. Friedrich, and R. Hiesgen, J. Electrochem. Soc. 165, F3139 (2018).

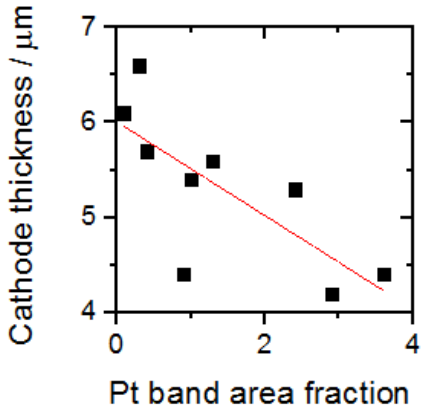
Local degradation analysis







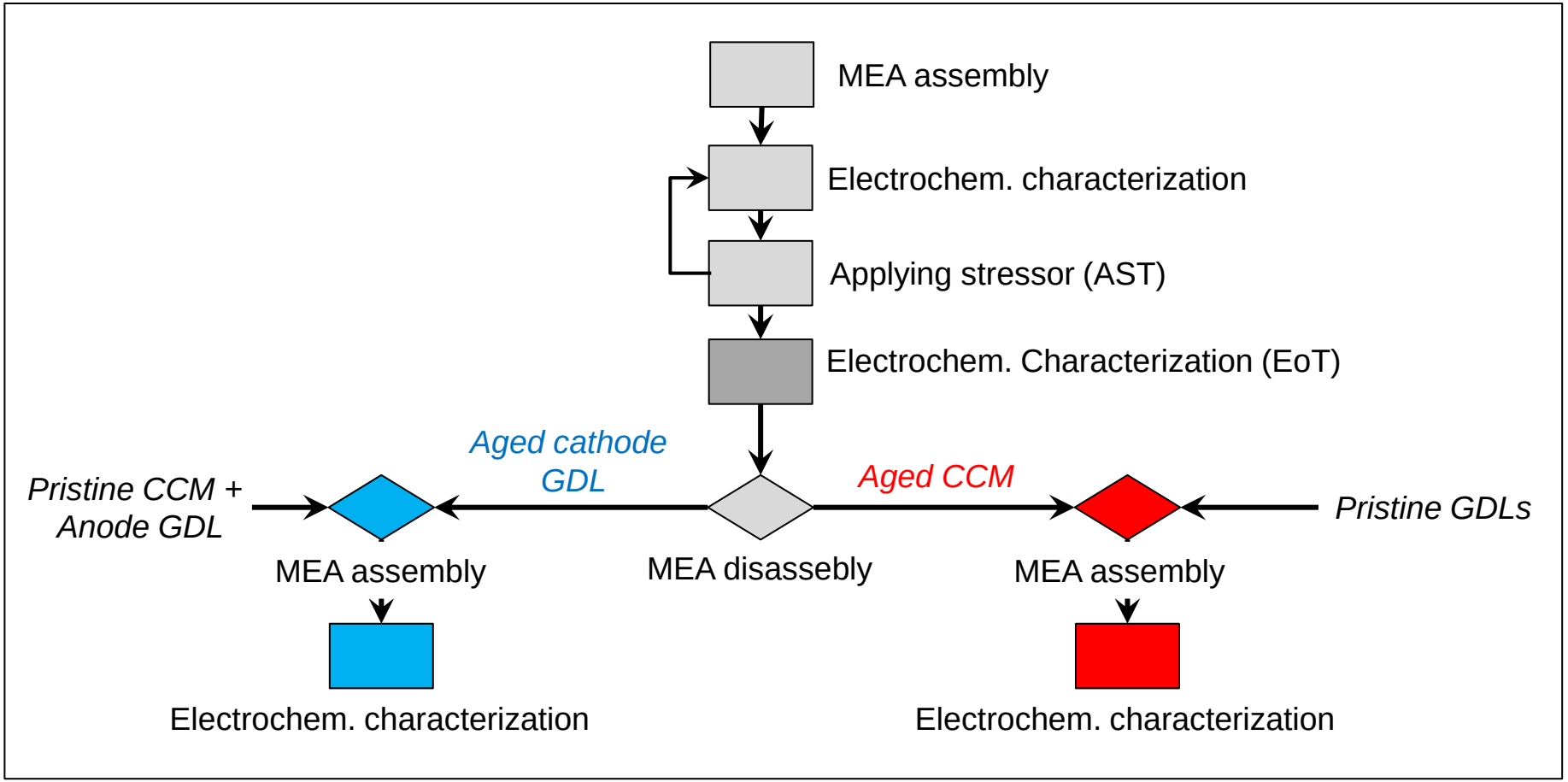




- Stationary operation is stressing condition leading to heterogeneous operation
- Local Pt band formation linked with CCL degradation

Investigation of stressors

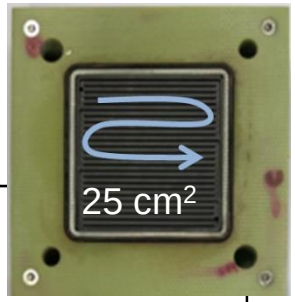
Determination of impact of stressors on MEA components

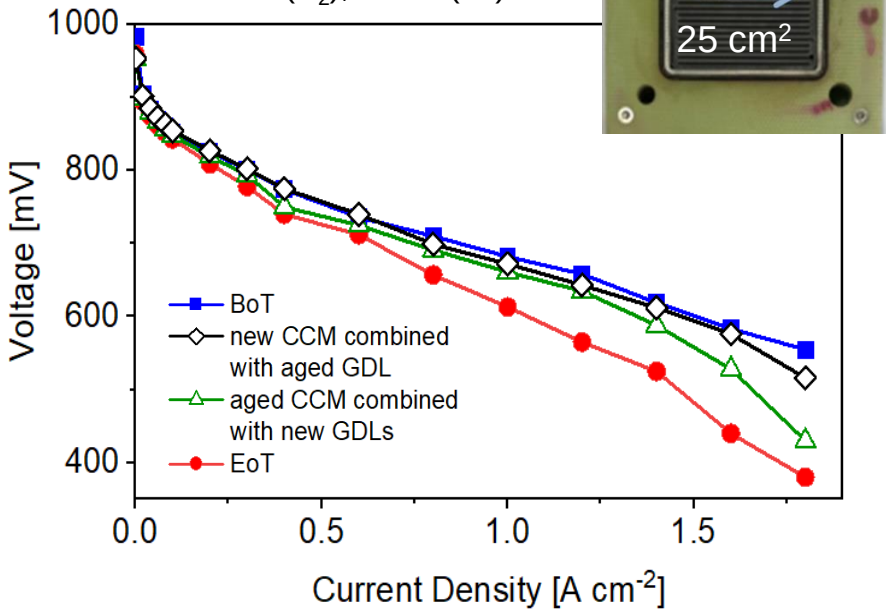


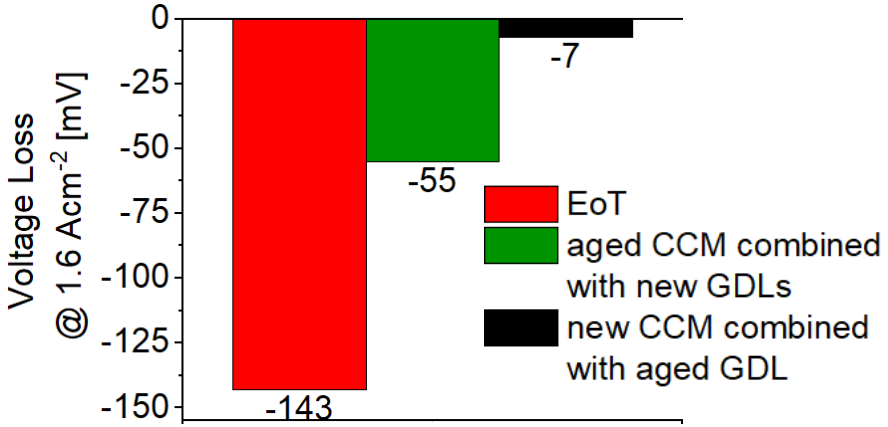
Investigation of stressors

Stressor: T = 95°C at 50%RH (219 h at 1 Acm^{-2})

T_{cell} = 80°C,
p_{abs}: 250 kPa (H_2), 230 kPa (air)
Stoich: 1.5 (H_2), 1.5 (air)
RH: 100% (H_2), 100% (air)





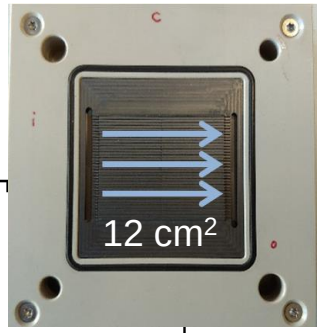


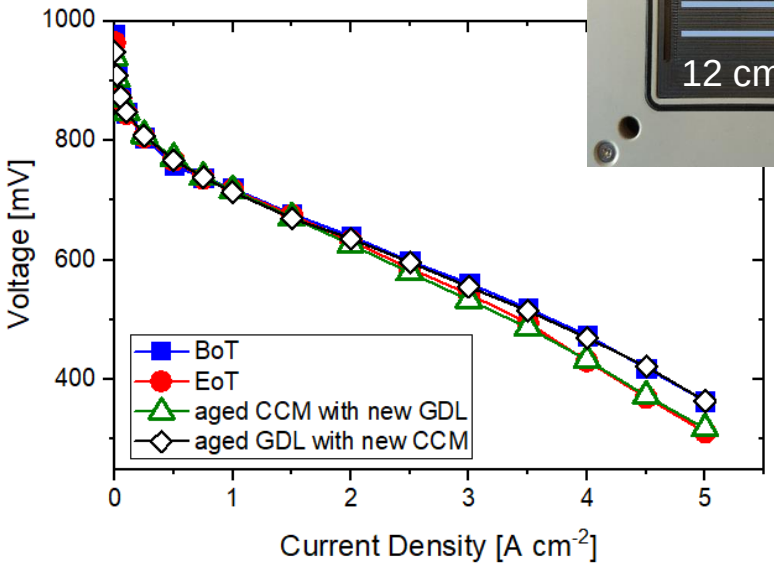
Separate analysis of GDL and CCM degradation does not explain all performance losses ➔ possible coupling effect

Investigation of stressors

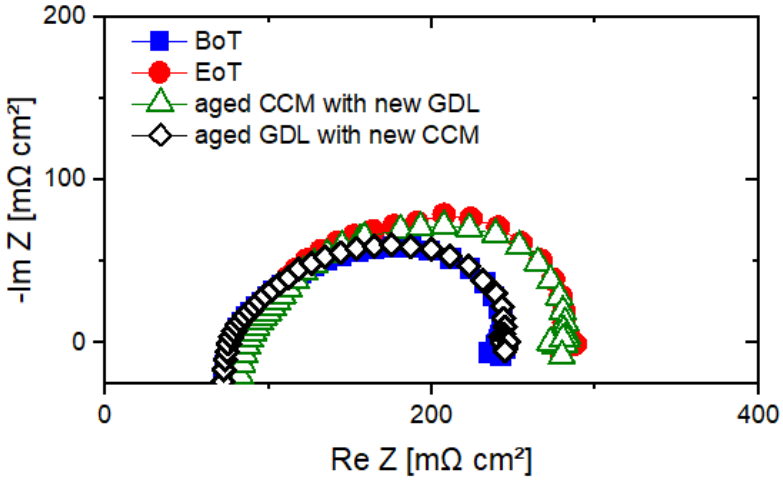
Stressor: High water flux (300h, 100%RH, j = 4 Acm^{-2})

T_{cell} = 65°C,
p_{abs}: 250 kPa (H_2), 230 kPa (air)
Stoich: 8 (H_2), 10 (air)
RH: 100% (H_2), 100% (air)





EIS @ 3 A cm^{-2}



- Degradation due to CCM responsible for 100% of losses

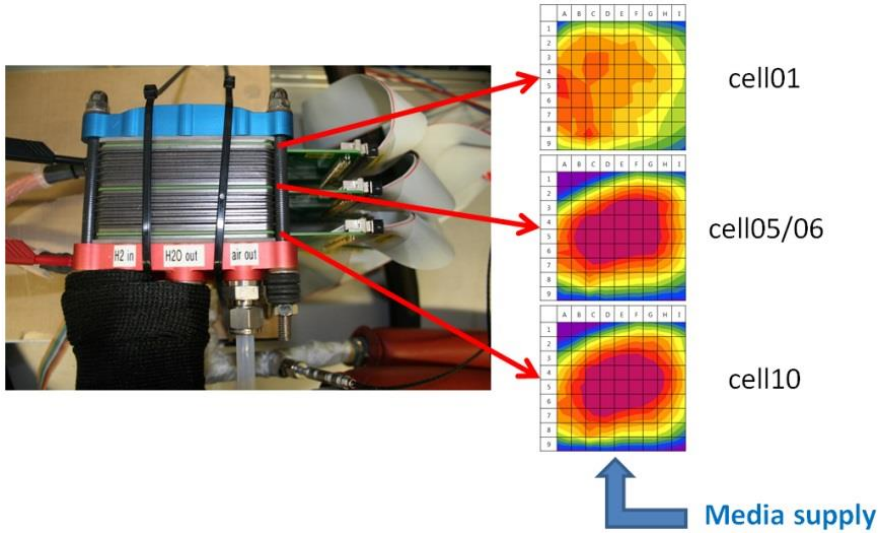
PEMFC system controller using on-line fault monitoring

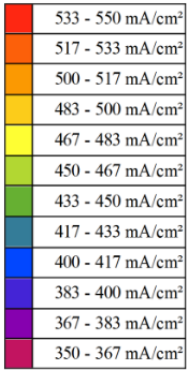
The National Centre for Research and Development

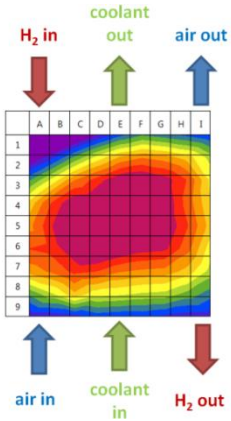
Federal Ministry of Education and Research

Objectives

- On-line fault detection in PEMFC stacks
- Identification of phenomena causing faults and degradation
- Identification of local critical conditions:
  - ➢ along flow field structure
  - ➢ in different single cells







Monitoring tools

- Parallel EIS in all cells
- Local current density measurement using 3 PCB

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On-line fault monitoring

The National Centre for Research and Development
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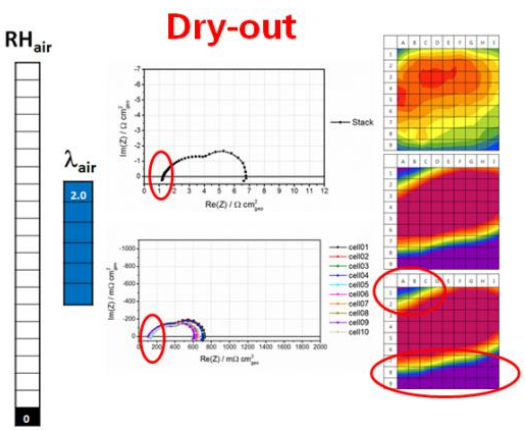
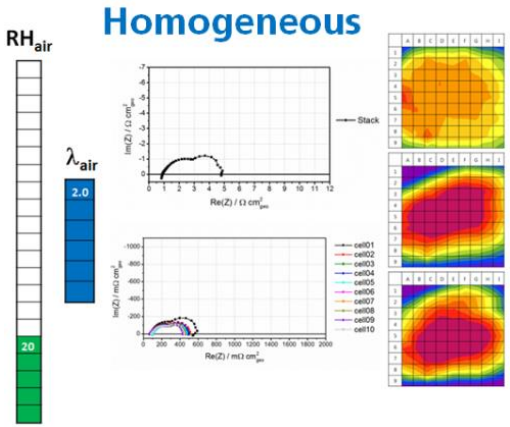
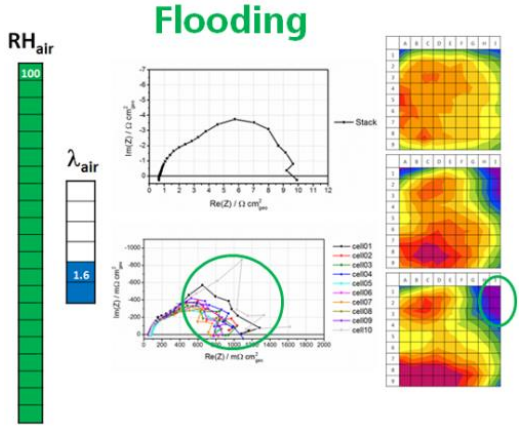
Analyzed phenomena: impact of 1) **load**, 2) **RH**, 3) **lambda**





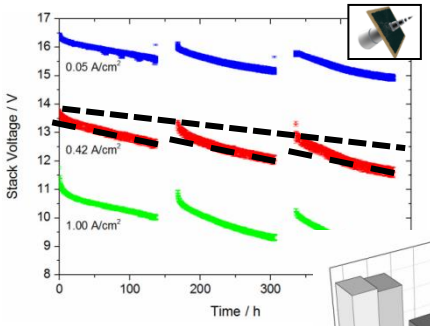


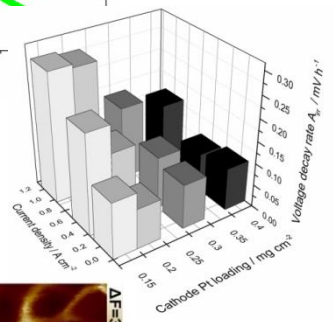
- Combination of EIS and current density monitoring (PCB) allows monitoring of single cells with improved sensitivity
- PCBs more sensitive to small changes in RH and to the detection of dry-out
- EIS more sensitive to flooding phenomena (diffusion resistance)

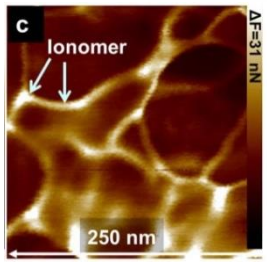
J.Mitzel et al., in preparation.

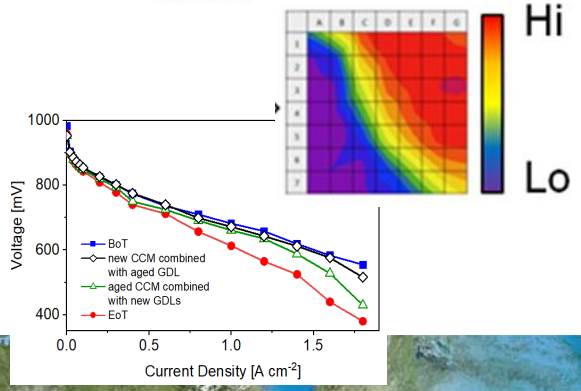
Summary

- Investigation of performance and degradation
- Study effect of Pt loading → low Pt loadings
- Analyze structure changes and effects
- Monitoring local current density distribution at singe cell and stack level
- Investigate effect of stressors on MEA components



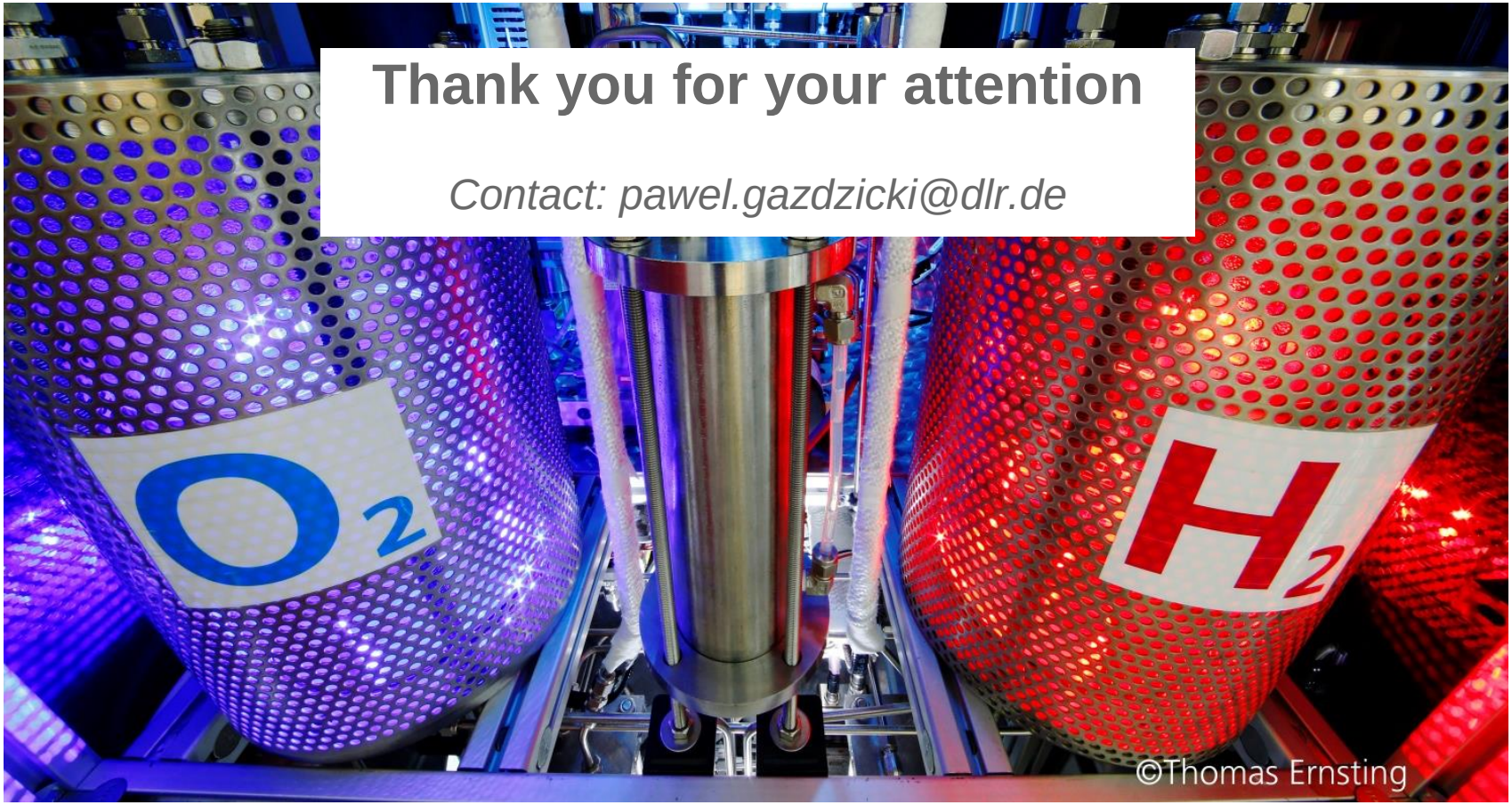






Thank you for your attention

Contact: pawel.gazdzicki@dlr.de



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