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Fuel cells in marine applications

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Funded by:
Federal Ministry for Digital and Transport

Coordinated by:
NOW-GMBH.DE

Project management:
PtJ Projektträger Jülich Forschungszentrum Jülich

MultiSchIBZ: Project summary and outlook

Elmar Pohl | OWI Science for Fuels gGmbH | Hamburg | 08.09.2022

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Agenda

- MultiSchIBZ at a glance
  - Project targets
  - Advantages SOFC Technology
- Highlights:
  - Additive manufactured heat-exchangers
  - Additive manunfactured anode off-gas recirculation
  - Demonstrators on lab scale
- Conclusion and Outlook

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sunfire

thyssenkrupp

MultiSchIBZ at a glance

- **Duration:** 01.09.2018 - 31.12.2021
- **Volume:** ~9 Mio. EURO
- **Project Coordination:** Since 2021 OWI Science for Fuels
  Till 2020 ThyssenKrupp Marine Systems

- **Major project-targets (only selected listed):**
  - Development, optimization and system integration of **BoP components**, especially the thermal and fluidic integration
  - Development and testing of **high-temperature recuperators** with additive manufacturing
  - Development of a **passive recirculation approach** of the anode exhaust gas
  - New development of a process gas module for **LNG**
  - Investigation of **catalysts for liquid fuel reforming**
  - Development of **water recovery** for catalysts for liquid fuel reforming
  - Concept development for **scaling** the FC module for target application

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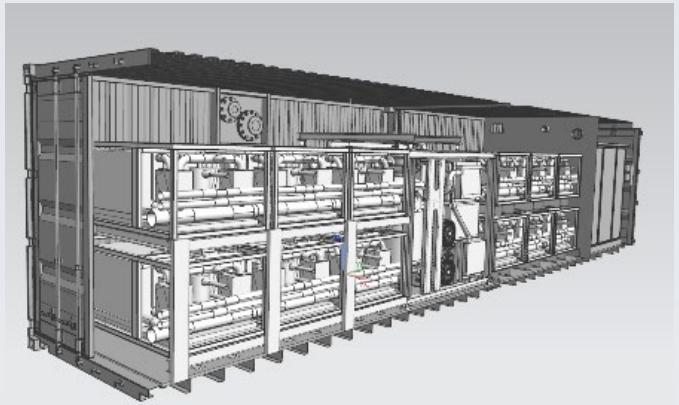
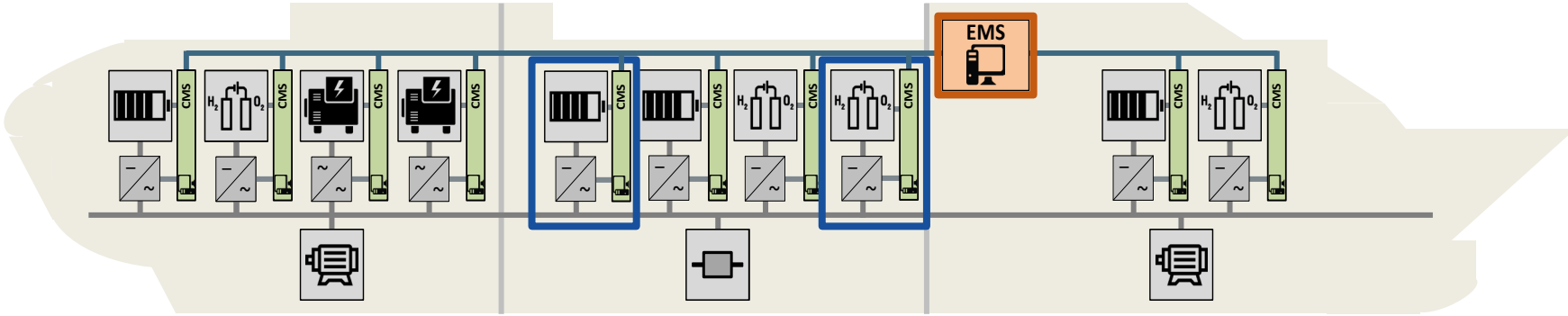
Why to deal with SOFC technology?

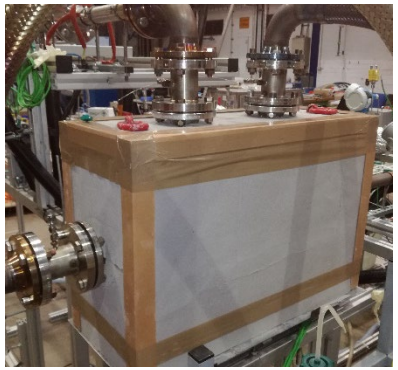
- Advantages SOFC technology within the MultiSchIBZ approach:
  - High electrical efficiency of 50-60 %
  - High overall efficiency of up to 90 %
  - Fuel flexibility, eFuels, GtL, HVO, ammonia, methanol, LNG, CNG etc.
  - Low emissions, including NOx, soot, no methane slip, vibration and noise
  - Ideal conditions for heat integration for covering heat demand on vessels

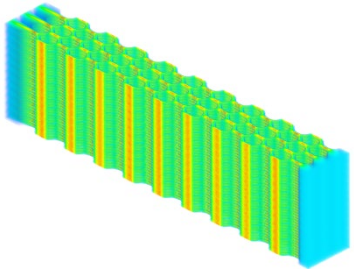




Highlights: Additive manufactured high temperature recuperators

Generation 1 | Generation 2 | Generation 3 | Generation 4

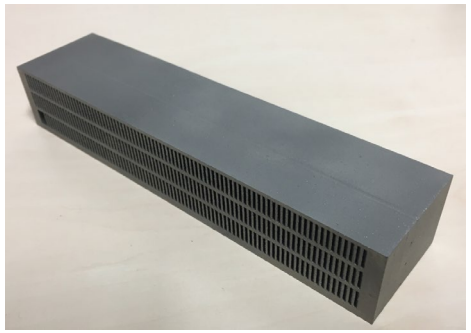





Dimensions

Power Density






- Comprehensive thermal characterization of the heat exchangers
- Power density could be increased by factor 25 compared to conventional tube heat exchangers

Highlights: Additive manufactured high temperature recuperators

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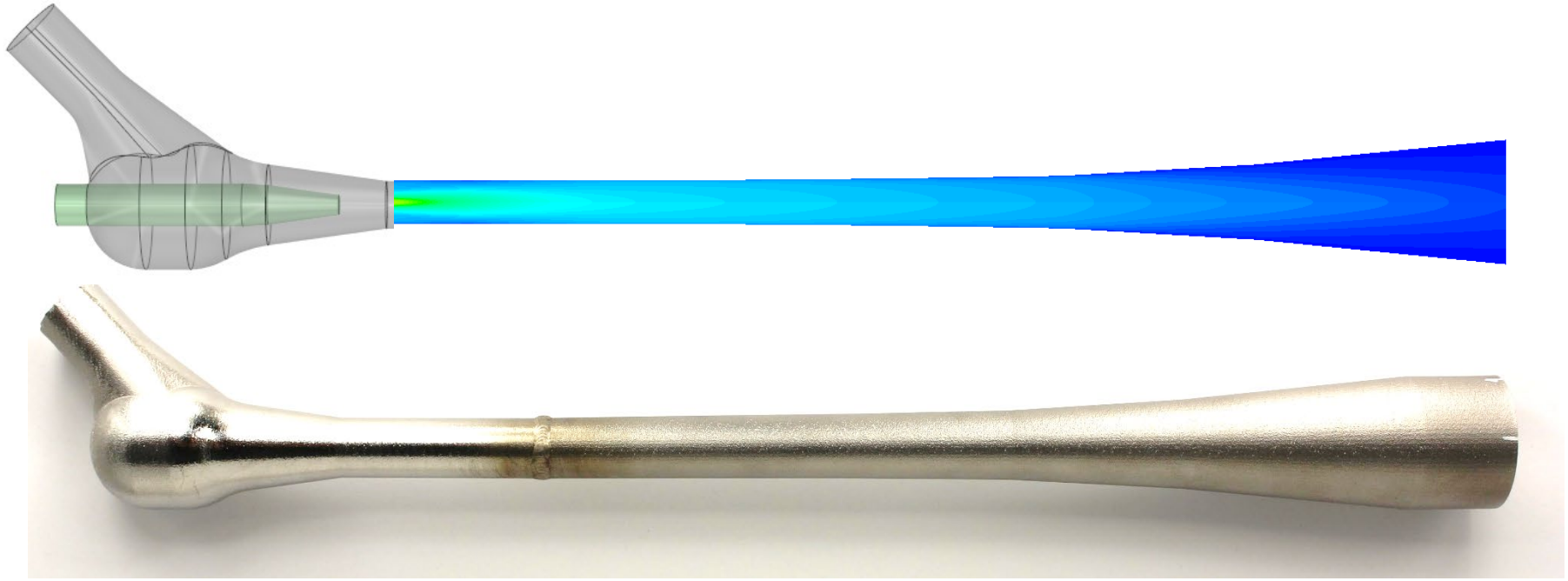
- Product development of novel heat exchangers and recuperators

- New high-performance recuperator: tube bundles manufactured using additive manufacturing process (SLM).
- Specific power up to 8 MW/m³: 25x smaller with the same power
- Gas-tight, pressure-resistant and high-temperature resistant up to 1,000°C
- Long service life thanks to stable material thicknesses

Highlights: Passive anode-offgas recirculation, manufacturing and testing

- Hot gas recirculation nozzle represents a technologically interesting alternative to the blower
- Manufacturing technology suitable for 3D printing due to fast manufacturing times and geometric degrees of freedom. Several 3D printed samples made of 1.4848 and 50 µm layer thickness
- Inner surface optimized by Hirtizing (an electrolytic surface treatment method and support structure removal) (target Rz = 10 µm)
- Recirculation nozzle was tested successfully on test rig for starting and operating conditions



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Highlights: eFuel-Path, lab scale full system

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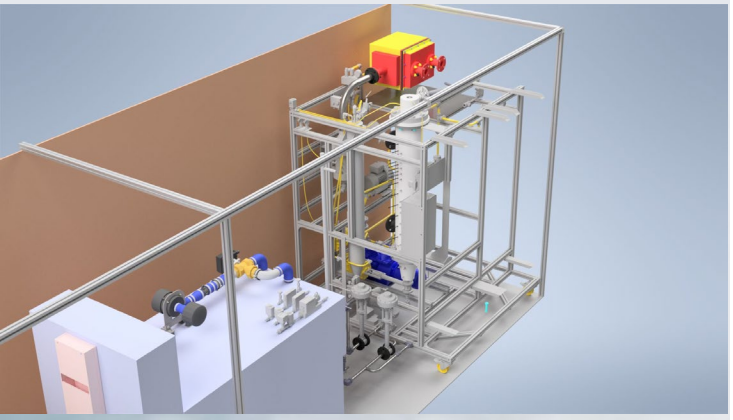
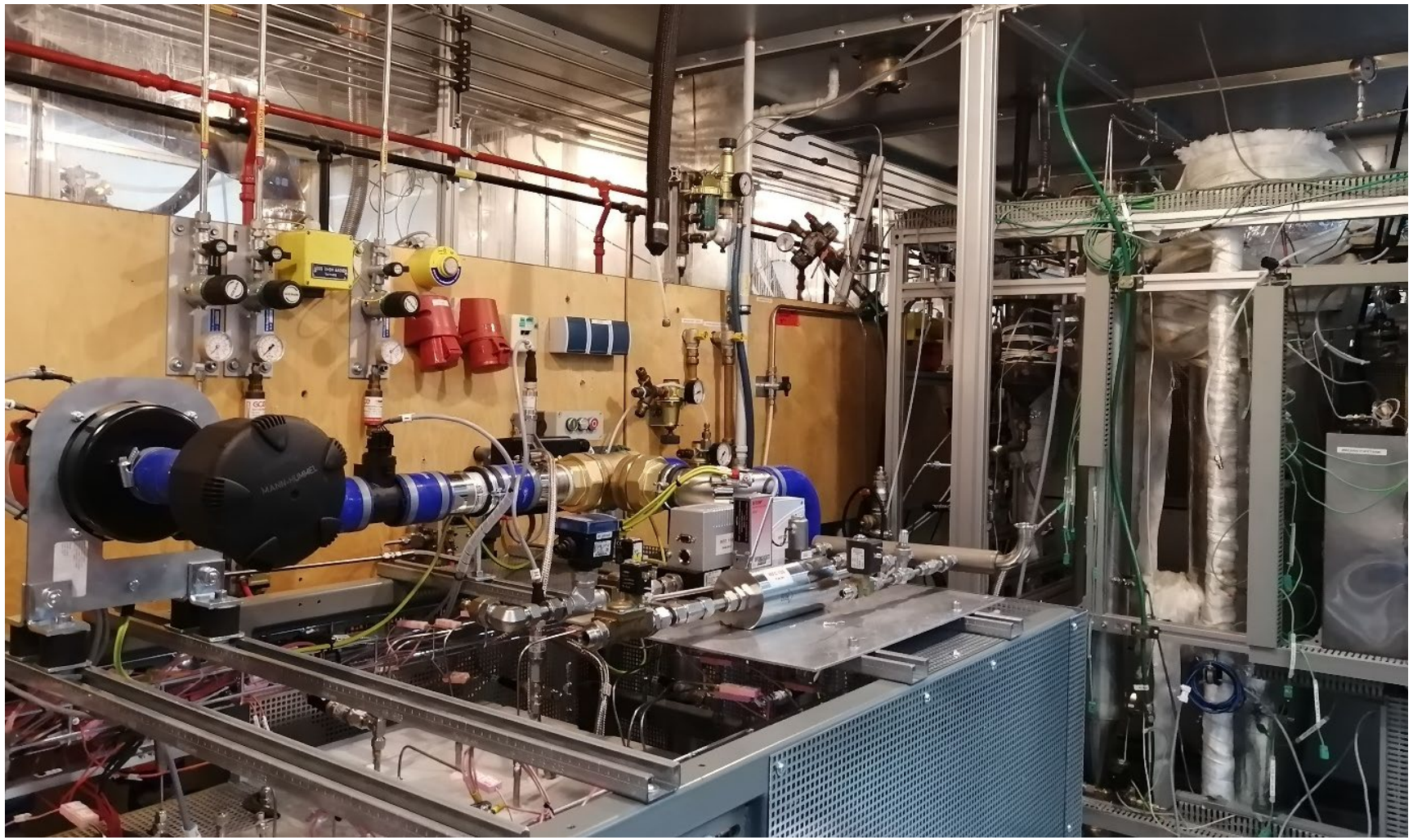
- Long-term test benches Diesel, HVO, GtL showed lifetime up to 10,000 h.
- Coupled reformer-SOFC System performed well.





Highlights: LNG-Path, lab scale full system

- At ZBT, a LNG-Path has been successfully set up.
- New high-performance recuperator with tube bundles manufactured using additive manufacturing process (SLM) are used in the process gas module.
- The reforming process does not require additional water dosing thanks to internal recycling of the process gases from the SOFC.
- A process design, scaling approaches for reactors and the first coordinated packaging designs are available. Their implementation is the goal of a planned follow-up project.

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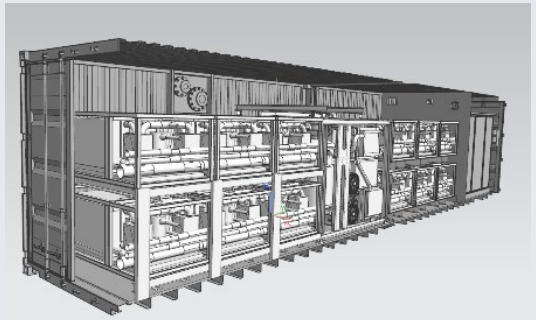
Conclusion

- Highest net **electrical efficiencies** of **58 to 60%** are obtained at maximum fuel stack utilization and an anode recirculation ratio of 70%
- Catalyst screening for eFuel application
  - Expected **lifetime up to 10.000 h** allows commercial application
- Demonstrators on lab scale
  - Diesel System:
    - Successful set-up of overall system
    - **Closed water balance** with simple water treatment achieved
  - LNG System:
    - Successful implementation of novel BoP Components (**additive manufactured heat-exchangers** etc.)
    - Scale-up (blueprint) for target application is ready.

Outlook: Roadmap MultiSchIBZ 2.0



Achieved goals in SchIBZ::

- Design of lab demonstrator
- Process optimization in the laboratory
- Diesel and LNG operation
- Component development and optimization

Planned goals in MultiSchIBZ 2.0:

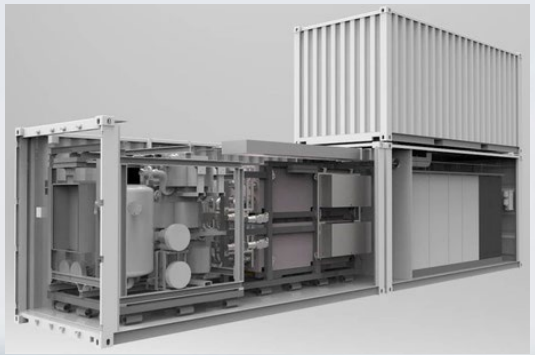
- Construction of a full-scale pilot plant and operation optimization
- Acceptance by class society and sea operation
- Multi-fuel operation including methanol and ammonia

MultiSchIBZ

MultiSchIBZ 2.0

2018 2020 2022 2024 2026

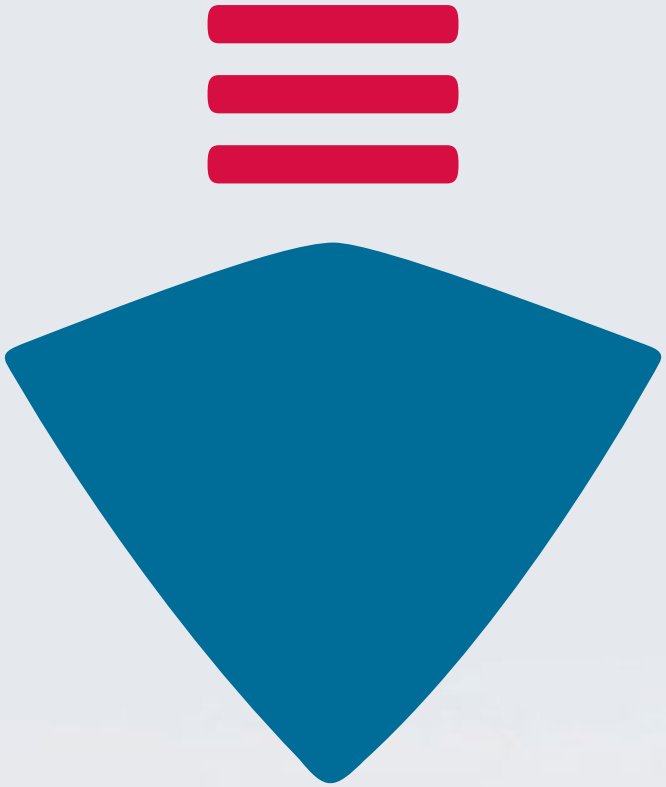
SchIBZ



Achieved goals in SchIBZ:

- Construction of a demonstrator 50 kWel
- Focus on diesel reformation (eFuels, Biofuels, etc)
- Acceptance by class society

- Demonstrator is still available in the project!



Herzlichen Dank!

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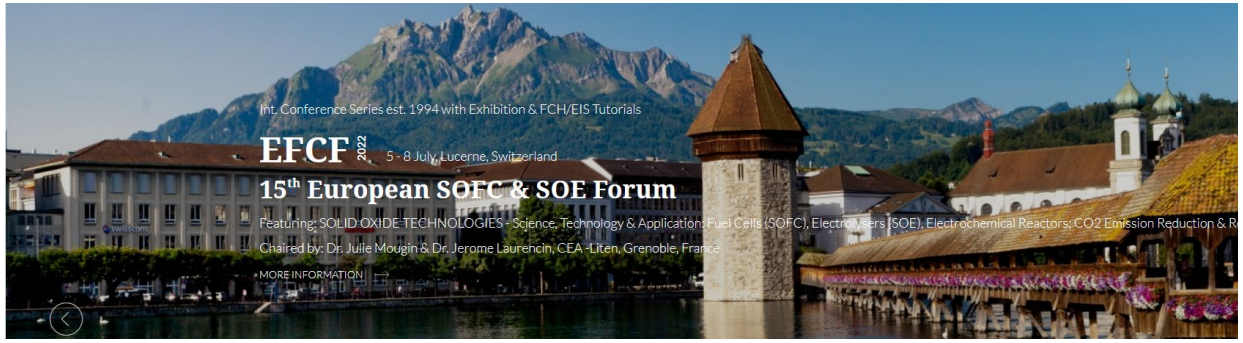
EFCF

5.-8. Juli, Luzern

Beiträge zum SOFC Forum

- **Progress in the development of LNG and Diesel-fueled SOFC systems for maritime applications (A1102).** Jan Hollmann (1), Marco Fuchs (1), Elmar Pohl (2), Oliver Heymann (2), Carsten Spieker (3), Ulrich Gardemann (3), Michael Steffen (3), Stephan Kabelac (1) (1) Institute of Thermodynamics, Leibniz University Hannover; Hannover/Germany (2) OWI Science for Fuels gGmbH; Herzogenrath; (3) Zentrum für BrennstoffzellenTechnik (ZBT GmbH); Duisburg;
- **Pre-reforming of liquid fuels for utilization in commercial SOFC systems (A1107)** Tobias Schiekel, Elmar Pohl OWI Science for Fuels gGmbH; Herzogenrath/Germany;
- **Investigation on Additive Manufactured High Temperature Alloys for SOFC Components (A1108)** Dagmar Kuckelberg, Elmar Pohl; OWI Science for Fuels GmbH; Herzogenrath/Germany;



Veröffentlichungen

Veranstaltung	***Titel***	**Autoren**	**Typ**	**Datum**	**Ort**
Electric & Hybrid Marine World Expo Virtual 2021	*Decentralized Ship Energy System with High Temperature Fuel Cells*	Lukas Kistner, Astrid Bensmann, Richard Hanke-Rauschenbach	Vortrag	19.01.2021	online
VDMA "Neues aus der AM Szene	*Anwendungsbeispiel 1.4828 Wärmeübertrager*	Philipp Schwarz	Vortrag	15.01.2021	online
Fuel Cells in Maritime Applications	*MultiSchIBZ*	Keno Leites	Vortrag	02.02.2021	online
Schiffbau Industrie 01/2021	MultiSchIBZ startet in nächste Projektphase		Artikel		Print
Energy Conversion and Management	*Optimal Design of Power Gradient Limited Solid Oxide Fuel Cell Systems with Hybrid Storage Support for Ship Applications*	Lukas Kistner, Astrid Bensmann, Richard Hanke-Rauschenbach	Journal Paper	under review	Print
Journal of Power Sources	*Techno-economic and Environmental Comparison of Internal Combustion Engines and Solid Oxide Fuel Cells for Ship Applications*	Lukas Kistner, Fritjof Schubert, Christine Minke, Astrid Bensmann, Richard Hanke-Rauschenbach	Journal Paper	under review	Print
Electric & Hybrid Marine World Expo Virtual 2021	*Comprehensive Techno-economic and Environmental Assessment for Cruise Ship Energy Systems*	Lukas Kistner, Astrid Bensmann, Richard Hanke-Rauschenbach	Vortrag	05.09.2021	online
Deutsche Wassserstoffvollversammlung	*3D-Druck-Rekuperatoren für SOFC-BZ-Systeme in Schiffen - hochtemperaturfest-gasdicht-ultrakompakt*	Wolfgang Bender	Vortrag	27.01.2021	online
Wärme- und Stoffübertragungskonferenz 2021	*Experimentelle Charakterisierung additiv gefertigter Kompakt-Hochtemperatur-Wärmeübertrager*	Marco Fuchs, Xing Luo, Stephan Kabelac	Poster	24.02.2021	Online
30. Deutscher Flammentag	*Experimentelle Charakterisierung additiv gefertigter Kompakt-Hochtemperatur-Wärmeübertrager*	Marco Fuchs, Xing Luo, Stephan Kabelac	Vortrag	28.09.2021	Hannover
Eurotherm 2020/21	*Thermal Performance Measurement Of Additive Manufactured High-Temperature Compact Heat Exchangers*	Marco Fuchs, Xing Luo, Stephan Kabelac	Vortrag	20.09.2021	Online

Highlights: 3DD Rekuperatoren

- Rekuperator wird als „Kreuzgegenstrom“ Wärmeübertrager ausgeführt.
- Das Vorgänger-Design im konventionellen Verfahren wurde bereits im Projekt SchIBZ2 erfolgreich erprobt.