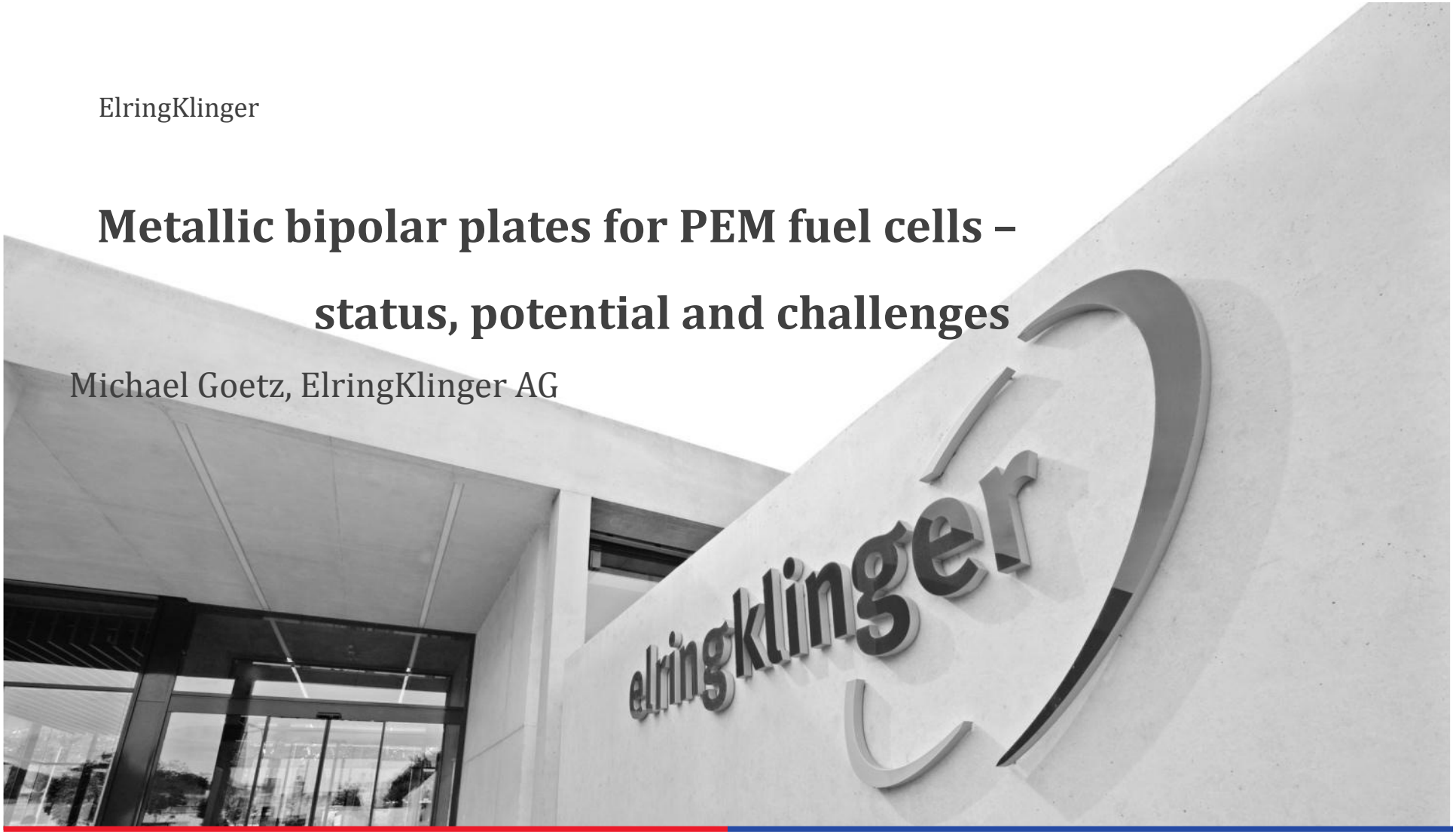
ElringKlinger

Metallic bipolar plates for PEM fuel cells – status, potential and challenges

Michael Goetz, ElringKlinger AG



elringklinger

ElringKlinger

Overview:

Company background ElringKlinger

ElringKlinger – PEM fuel cell products

Bipolar plates:

- concept and production details
- status of development & references
- open issues / possible drawbacks
- commercial potential of metal BPP vs. graphitic BPP
- outlook

Company History

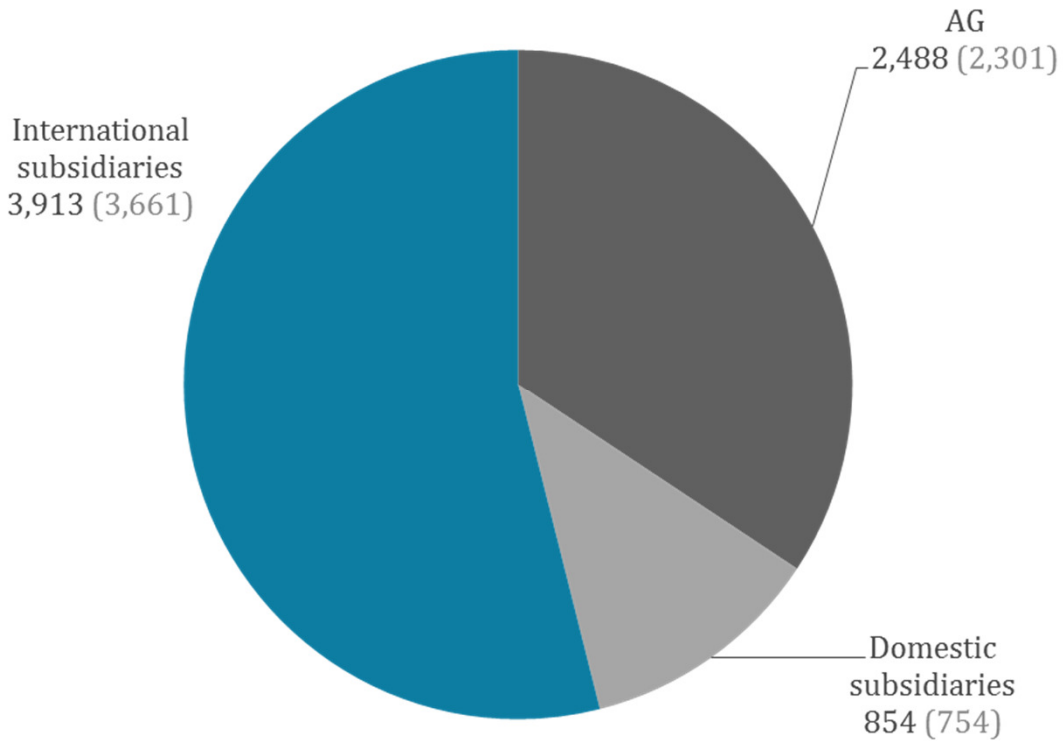
1879	Foundation of Paul Lechler in Stuttgart, Germany (later: Elring GmbH)
1885	Foundation of Richard Klinger in Vienna, Austria
1994	Merger of Elring GmbH and Richard Klinger Automotive to Elring Klinger GmbH
2000	Merger of Elring Klinger GmbH and ZWL Grundbesitz- und Beteiligungs-AG (former Holding Company of Elring Klinger GmbH), renaming as ElringKlinger AG
2008	Acquisition of Sevex AG based in Sevelen, Switzerland
2011	Acquisition of the Static Flat Gaskets business of the Freudenberg Group (Germany, France, Italy)
2011	Takeover of a 66.7% interest in the Swiss Hug Group based in Elsau, Switzerland (since 2013: 93.67%)
2013	Hummel Formen GmbH, based in Lenningen, Germany, is merged into the ElringKlinger AG
2014	ElringKlinger Kunststofftechnik, a subsidiary of the ElringKlinger Group, took over the specialty plastics manufacturer Polytetra GmbH (Mönchengladbach, Germany)

Employees ElringKlinger Group worldwide

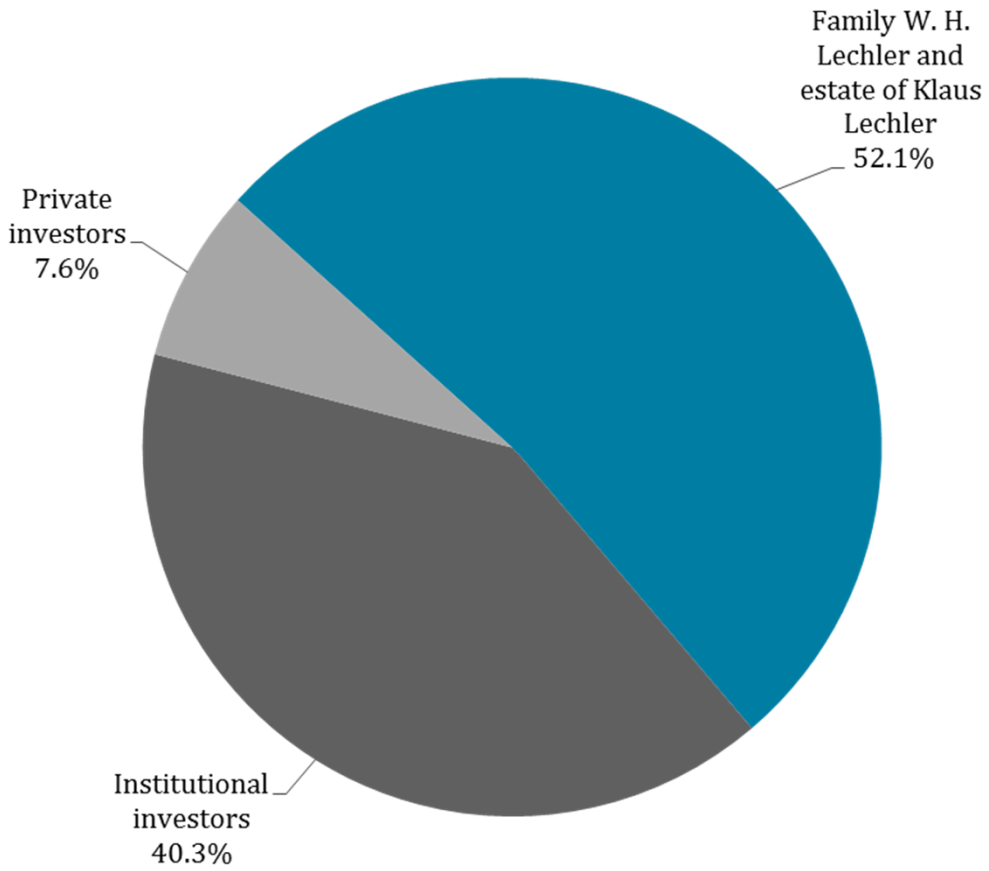
as of December 31, 2014 (py)

Group
7,255 (6,716)
+ 8.02%

Germany
3,342 (3,055)



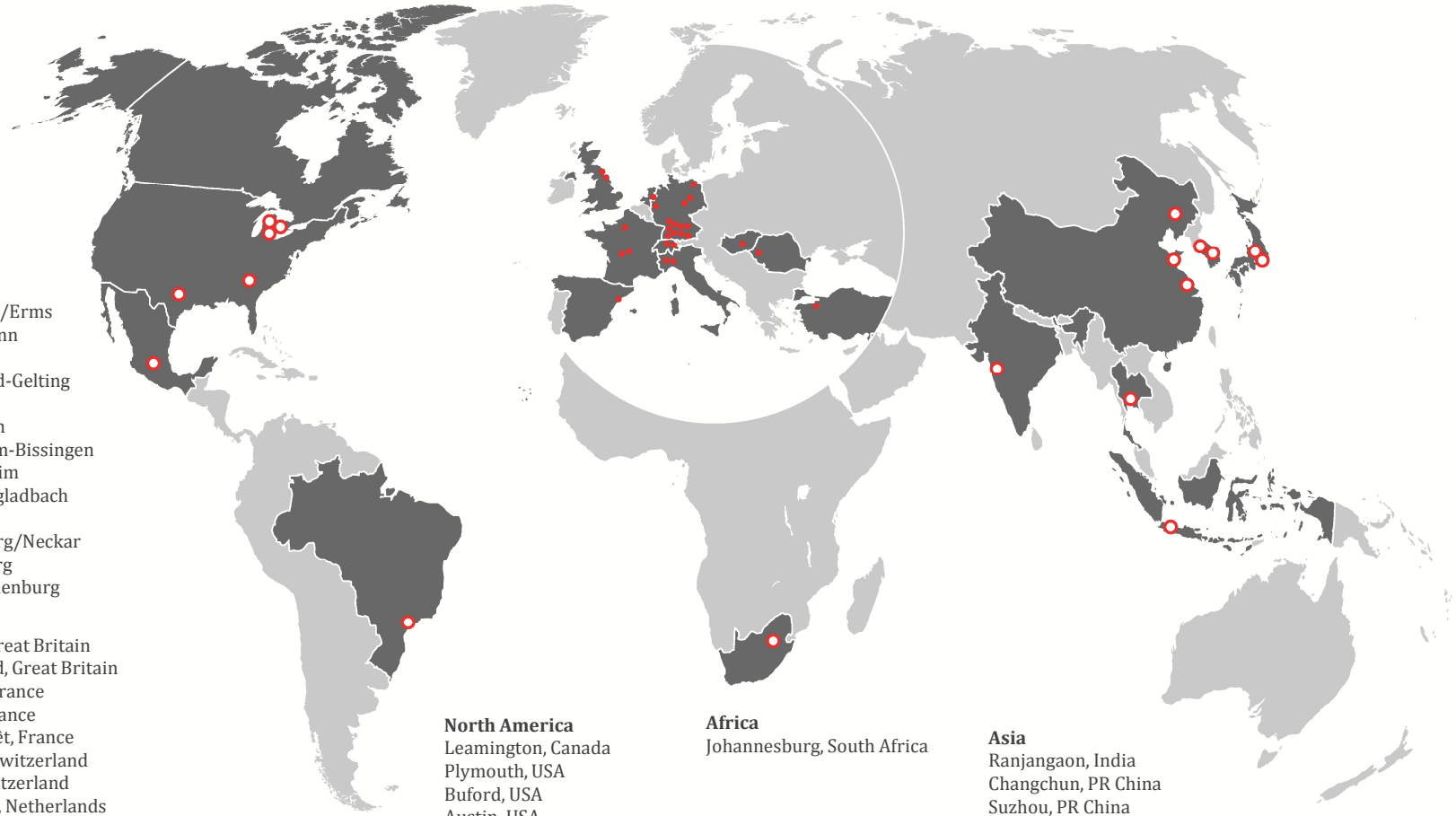
Shareholder structure*



* Based on information available to the company as of December 31, 2014

ElringKlinger

Worldwide



Germany
Dettingen/Erms
Langenzenn
Runkel
Geretsried-Gelting
Thale
Lenningen
Bietigheim-Bissingen
Heidenheim
Mönchengladbach
Idstein
Rottenburg/Neckar
Magdeburg
Neubrandenburg

Europe
Redcar, Great Britain
Gateshead, Great Britain
Nantiat, France
Poissy, France
Chamborêt, France
Sevelen, Switzerland
Elsau, Switzerland
Enschede, Netherlands
Reus, Spain
Settimo Torinese, Italy
Milan, Italy
Kecskemét-Kádafalva, Hungary
Timisoara, Romania
Bursa, Turkey

North America
Leamington, Canada
Plymouth, USA
Buford, USA
Austin, USA
Warren, USA
Toluca, Mexico

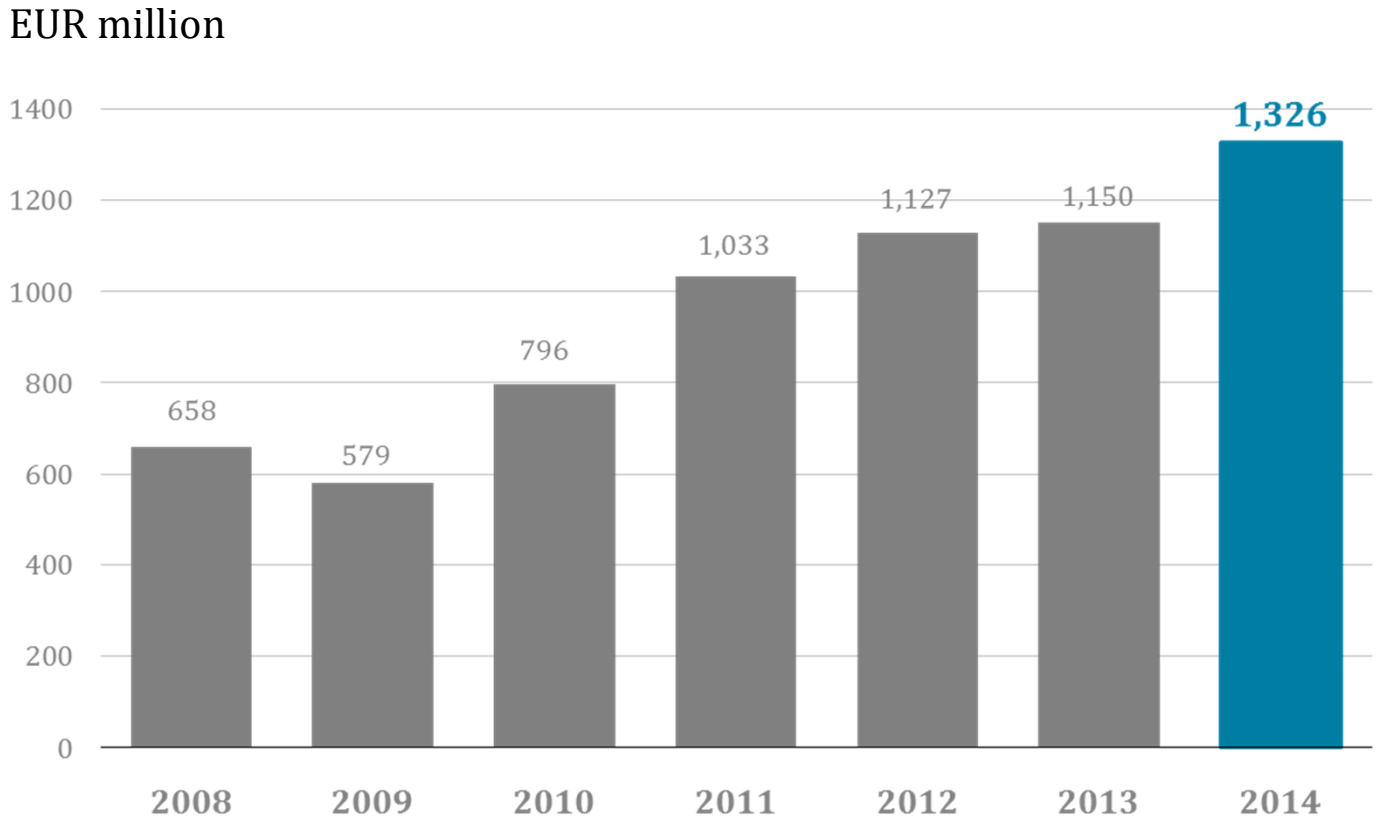
South America
Piracicaba, Brazil

Africa
Johannesburg, South Africa

Asia
Ranjangaon, India
Changchun, PR China
Suzhou, PR China
Qingdao, PR China
Gumi, South Korea
Seoul, South Korea
Tokyo, Japan
Saitama, Japan
Karawang, Indonesia
Bangkok, Thailand

ElringKlinger

Group Sales



ElringKlinger

Divisions

Cylinder-head gaskets

Specialty gaskets

Plastic modules

Lightweight plastic components

Shielding systems

Aftermarket

E-Mobility

Fuel cells

Exhaust gas purification

Engineered plastics

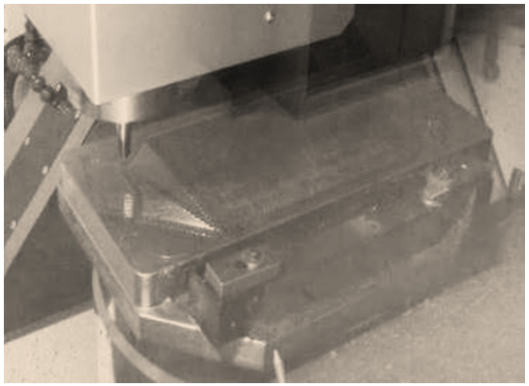
Engine testing services

Tooling technology

Core Competences

Sheet metal forming

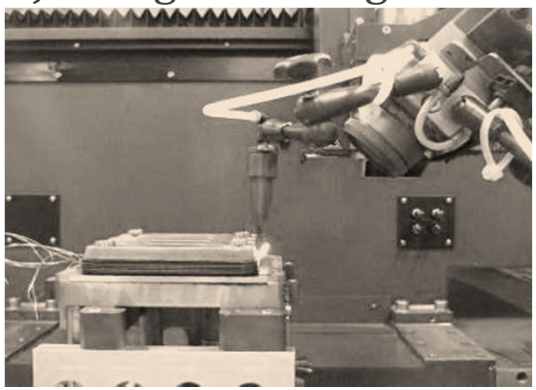
Injection molding



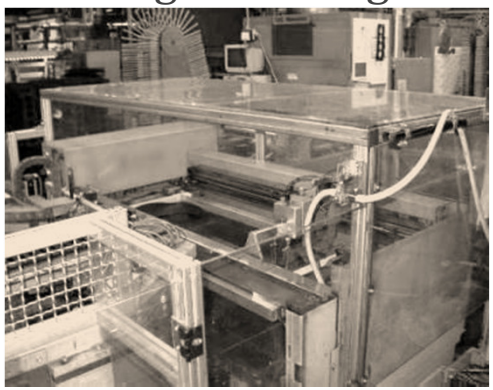
In house tooling

industrial processes, quality assurance

Joining technologies



Coating technologies



Assembly

Main Stack Components:

- MEA-components: membrane, catalyst layer, GDL

  → no competence at ElringKlinger

- sealings

  → core competence at ElringKlinger

- bipolar plates

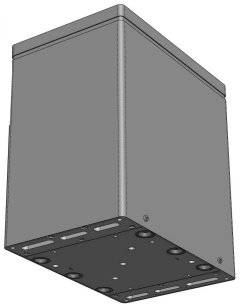
  → metal forming and joining core competence at ElringKlinger

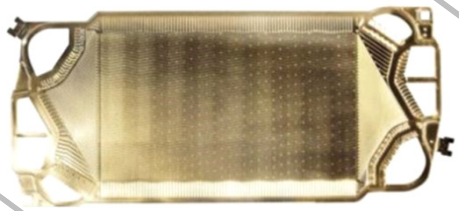
- end plate / clamping system and housing

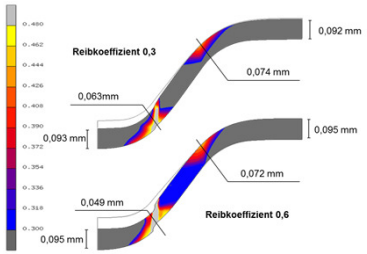
  → injection molding of high performance plastics core competence at ElringKlinger

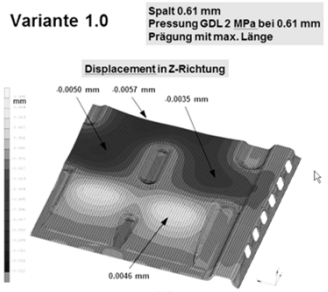
The product PEMFC-stack provides excellent added value for ElringKlinger!

Industrial production, Process-Know how,

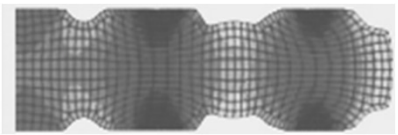






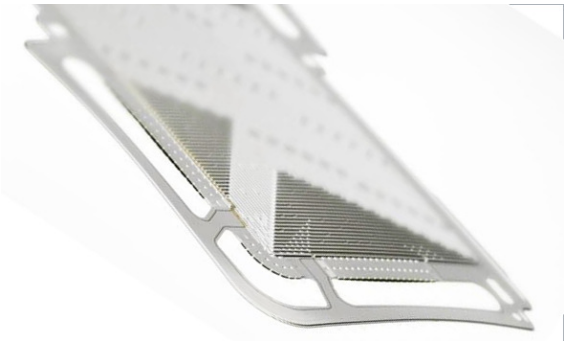


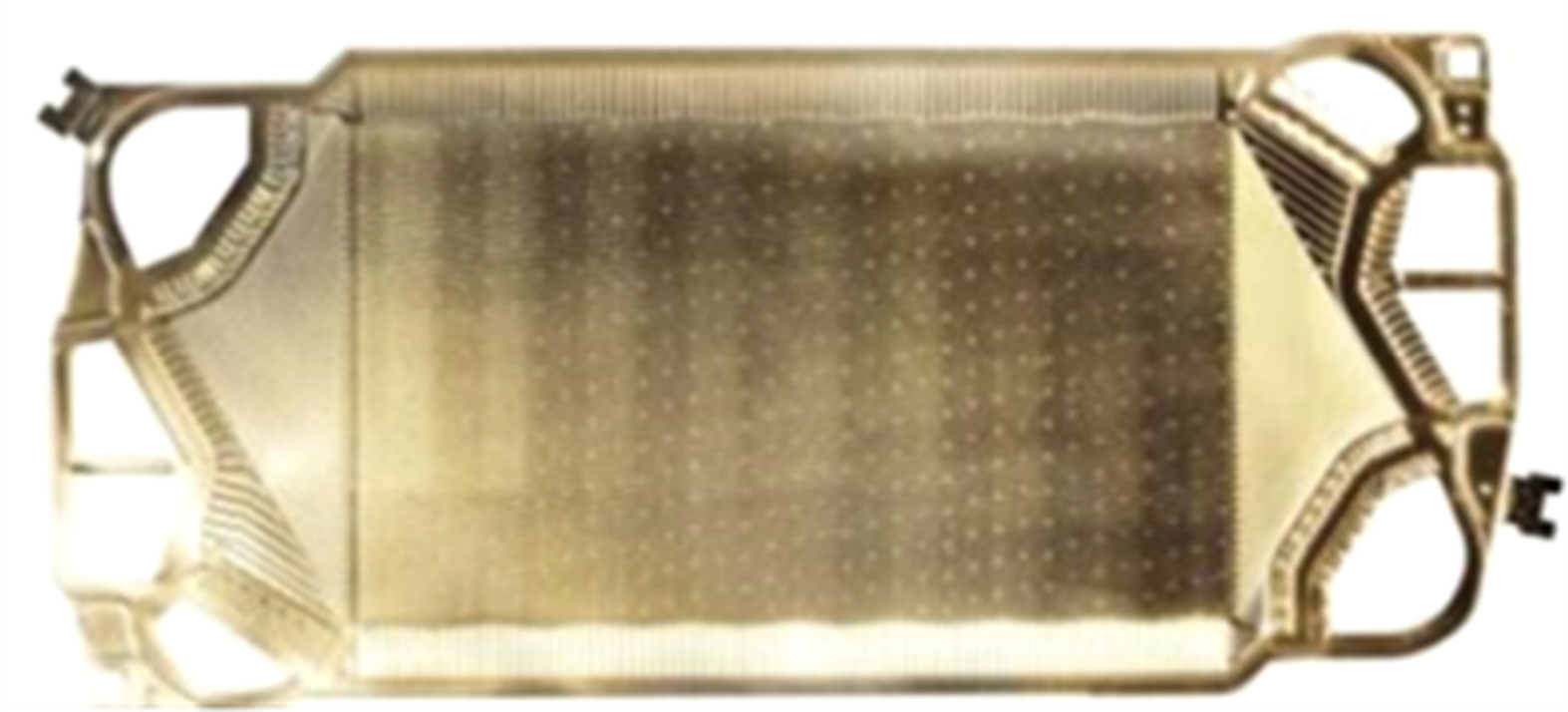
Technology-/ product-Know how, simulation (stamping, FEM), tooling, process optimisation, …



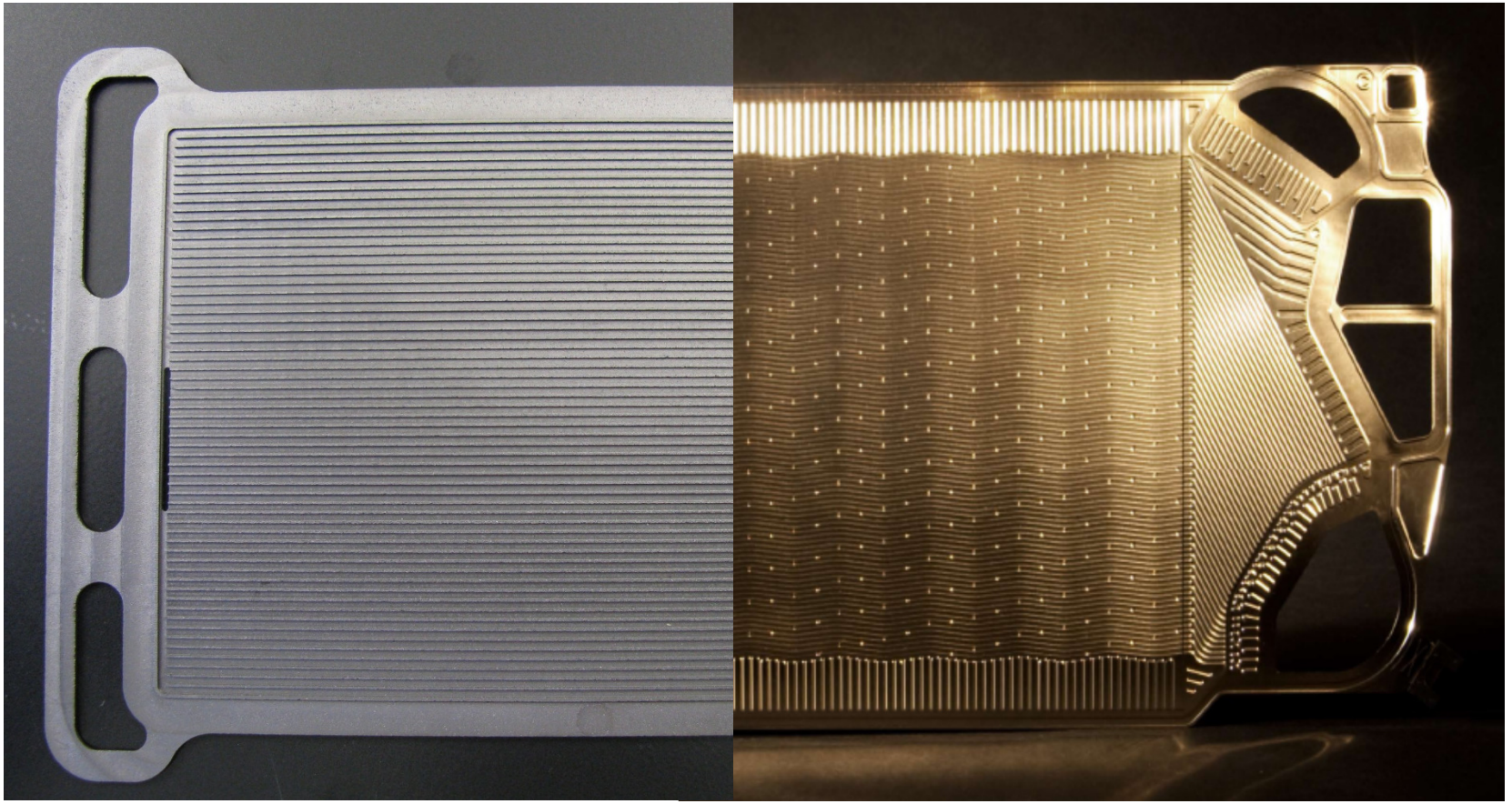
FEM model of an elastomer sealing

product – bipolar plate





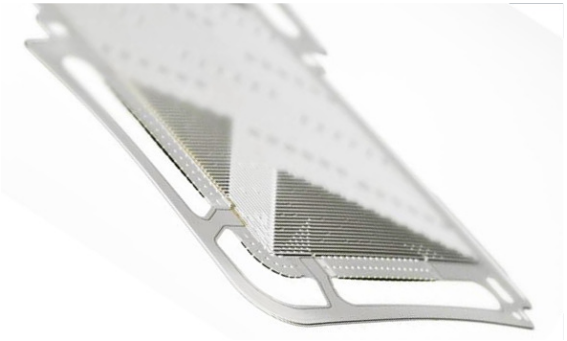
Bipolar plate unit



graphite-compound

stainless steel

Metallic vs. graphitic bipolar plates



Status:

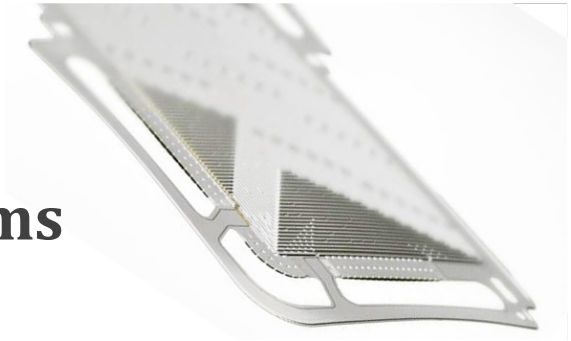
Graphitic bipolar plates

- easy prototype production by machining
- sharp features possible
- deep channels theoretically possible
- corrosion resistance proven
- mechanical strength very low
- machining extremely expensive
- also molding slow and expensive, radii and angles are needed then
- achievable cell pitch 4 mm

Metallic bipolar plates

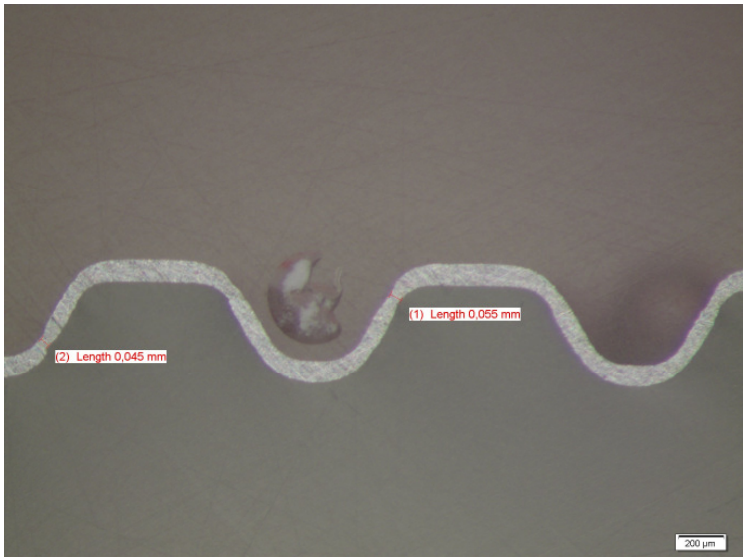
- expensive tooling and equipment needed
- radii and angles inevitable (→ smaller contact area to GDL)
- low material cost
- very quick production in compressive die sets (< 2s / part)
- coating is needed for good conductivity
- base material must be corrosion resistant
- achievable cell pitch 1,5 mm

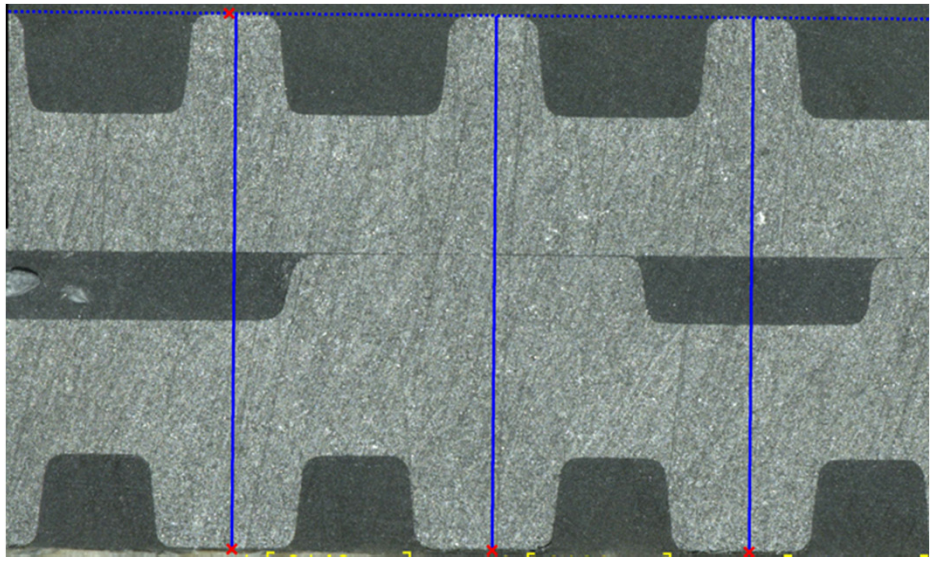
Metallic bipolar plates – potential problems



- Performance lower due to limitations in geometries
- Lifetime problems due to limitations in geometries
- Inhomogenous coolant distribution (→ coolant flowfield dependant on gas flowfields)
- Contamination due to release of metal ions (catalyze oxidative attack of ionomer)
- Increase in ICR due to coating degradation
- Cost issues due to coating – current status: galvanic gold <20 nm

PEMFC-Stack NM 5 vs. NG3 – plate geometry details





Stack NM5

cell pitch 1,5 mm

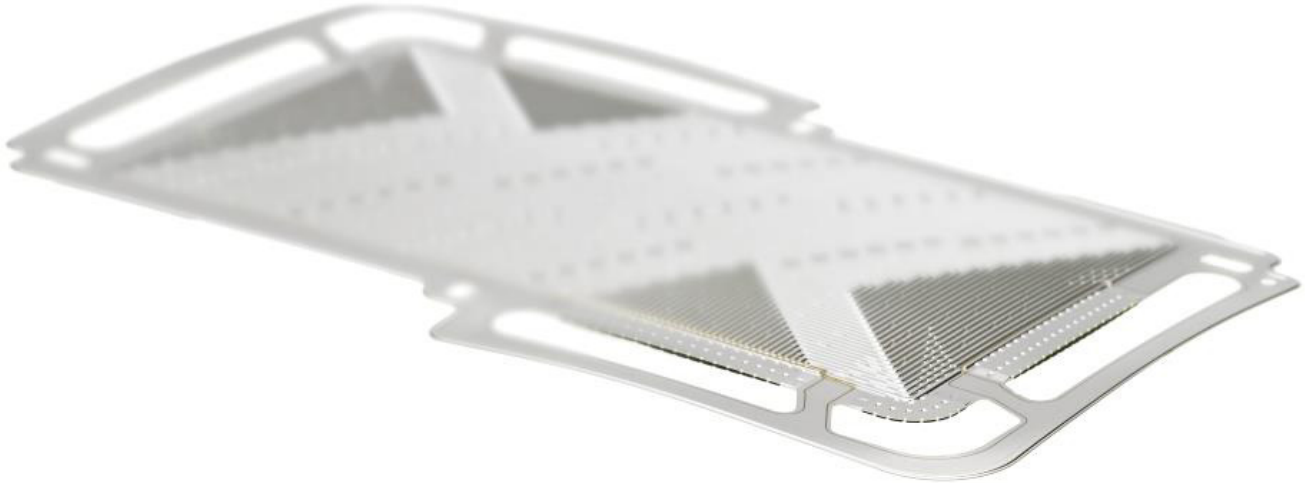
Stack NG3

cell pitch 4 mm

Sheet metal bipolar plates as an ElringKlinger Product

Product definition:

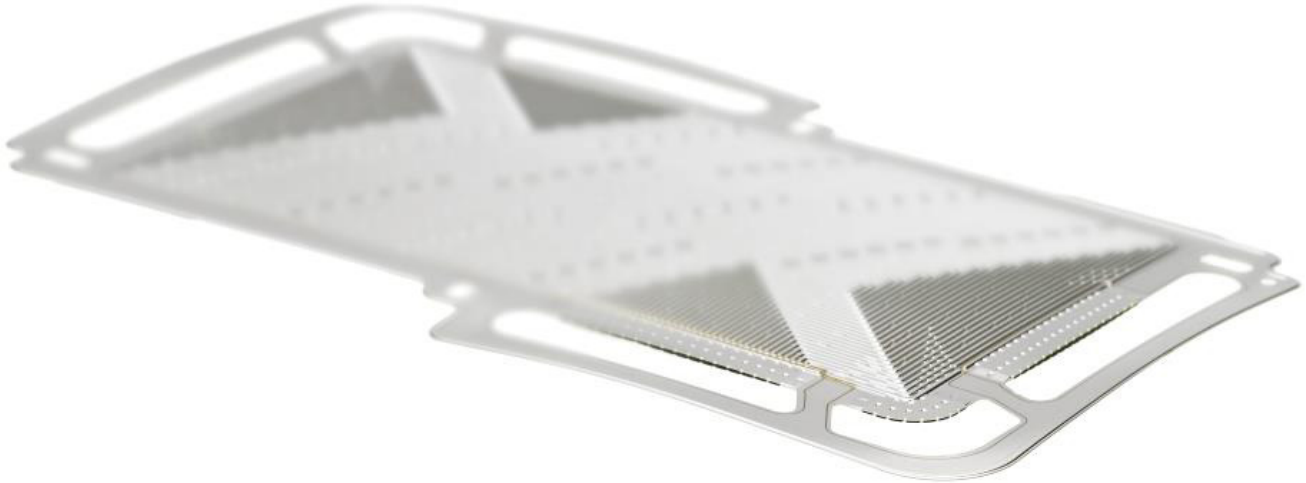
- Multi layer sheet metal assembly
- Coated layers – coated assembly
- Stack sealing option on assembly



Sheet metal bipolar plates as an ElringKlinger Product

Production steps:

- Stamping and die cutting in progressive die
- Laser-welding
- Seal application
- Testing

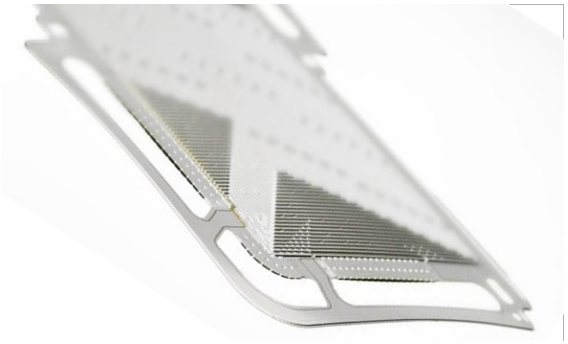


Sheet metal bipolar plates as an ElringKlinger Product

Production in progressive die:

- Several subsequent tools in one press
- Parts are transferred to the next tool every time the press opens
- Optimum cycle time and use of equipment

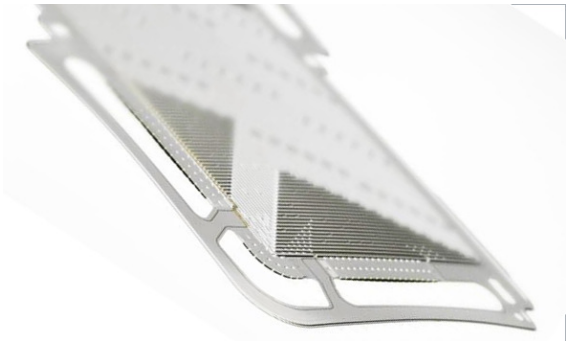
Metallic bipolar plates – stamping process



Status:

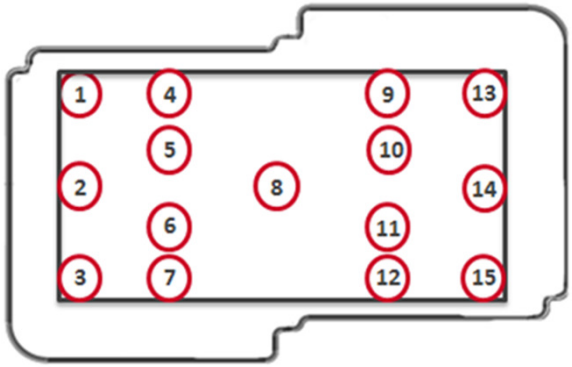
- Production equipment available (unique press with high tonnage, stiffness and precision for optimum flow field tolerances)
- Ready for mass production (tests with high volume progressive die sets on production presses finalized)
- Production rate > 40pcs/min
- Process capability proven

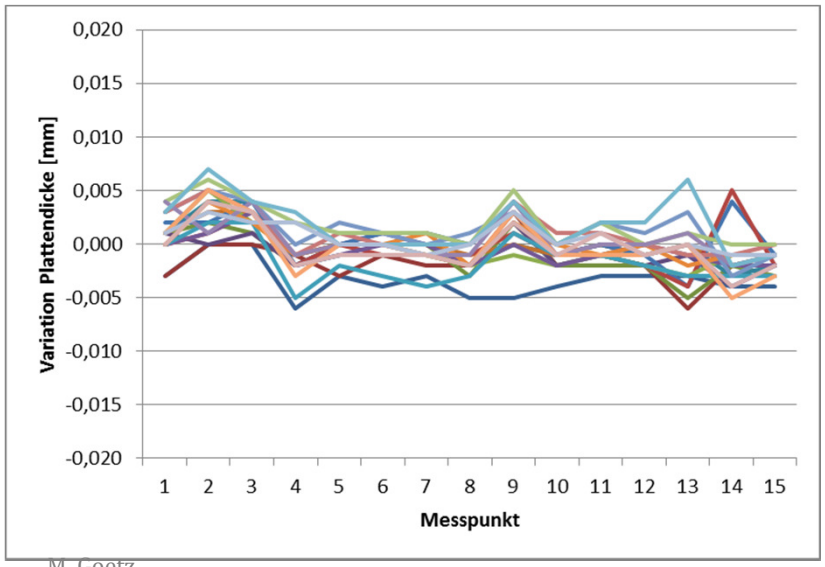
PEMFC-components: bipolar plates

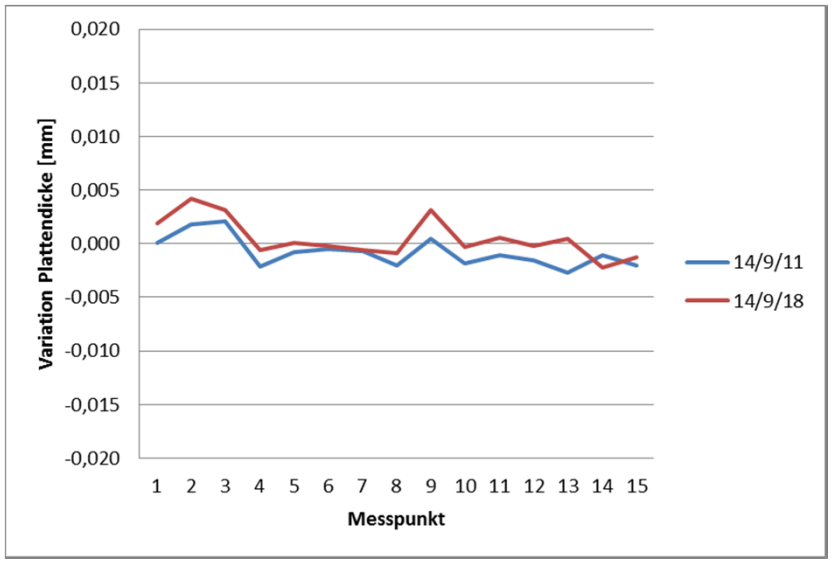


Highest precision and repeatability – Stack NM5

- Variation plate thickness (per batch) < ± 10 µm
- Variation plate thickness for a single plate < ± 5 µm
- Repeatability better than 4µm
  (batch to batch – tool changing in between)







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PEMFC-Stack NM 5

Picture shows 80 cell stack with prototype end plates

Stack based on metallic bipolar plates,

- Industrial producibility proven

Lifetime test ongoing, currently > 5000 hrs

Power density pressurized
(2,5 bar_a, 340 A @ U_C=0,6 V):

- 7,2 kW/l (active area),
- 6,4 kW/l (CCM size),
- 4,0 kW/l (cell stack w/o end plates)

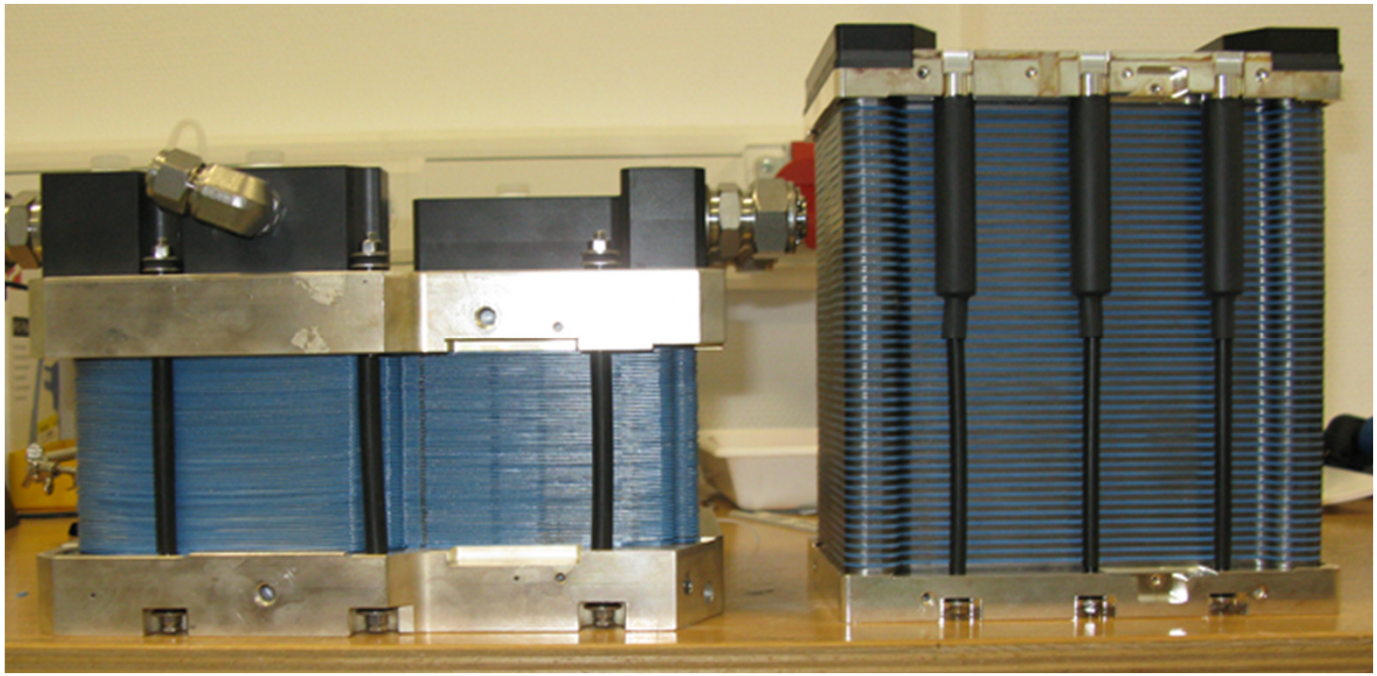
i.e. stack NM 5- 48 cells

10 kW @ 2,5 bar_a

6,5 kW @ 1,2 bar_a

L /W/H (mm): 243/161/73 (w/o end plates)

PEMFC-Stack NM 5 vs. NG3



Stack NM5

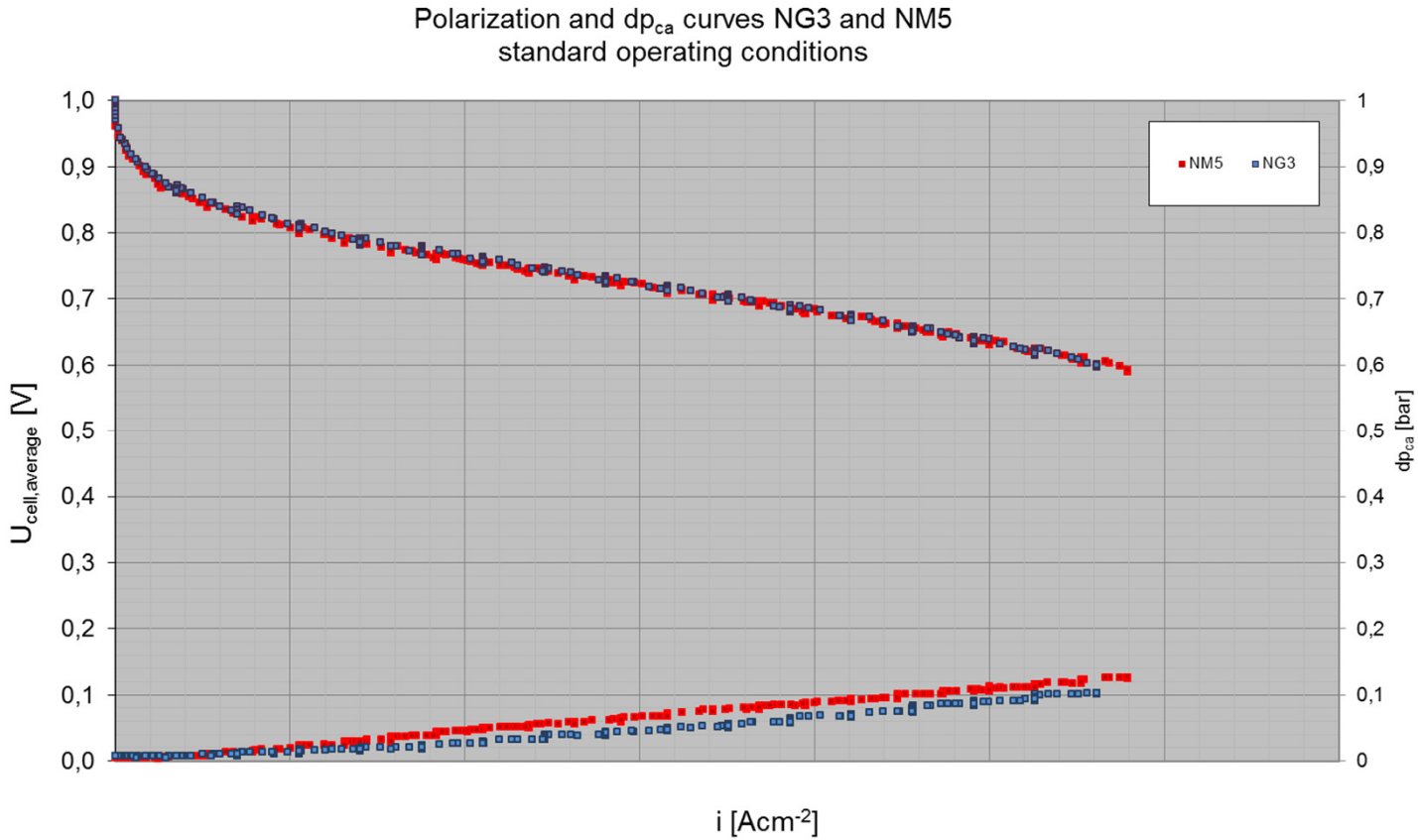
cell pitch 1,5 mm

Stack NG3

cell pitch 4 mm

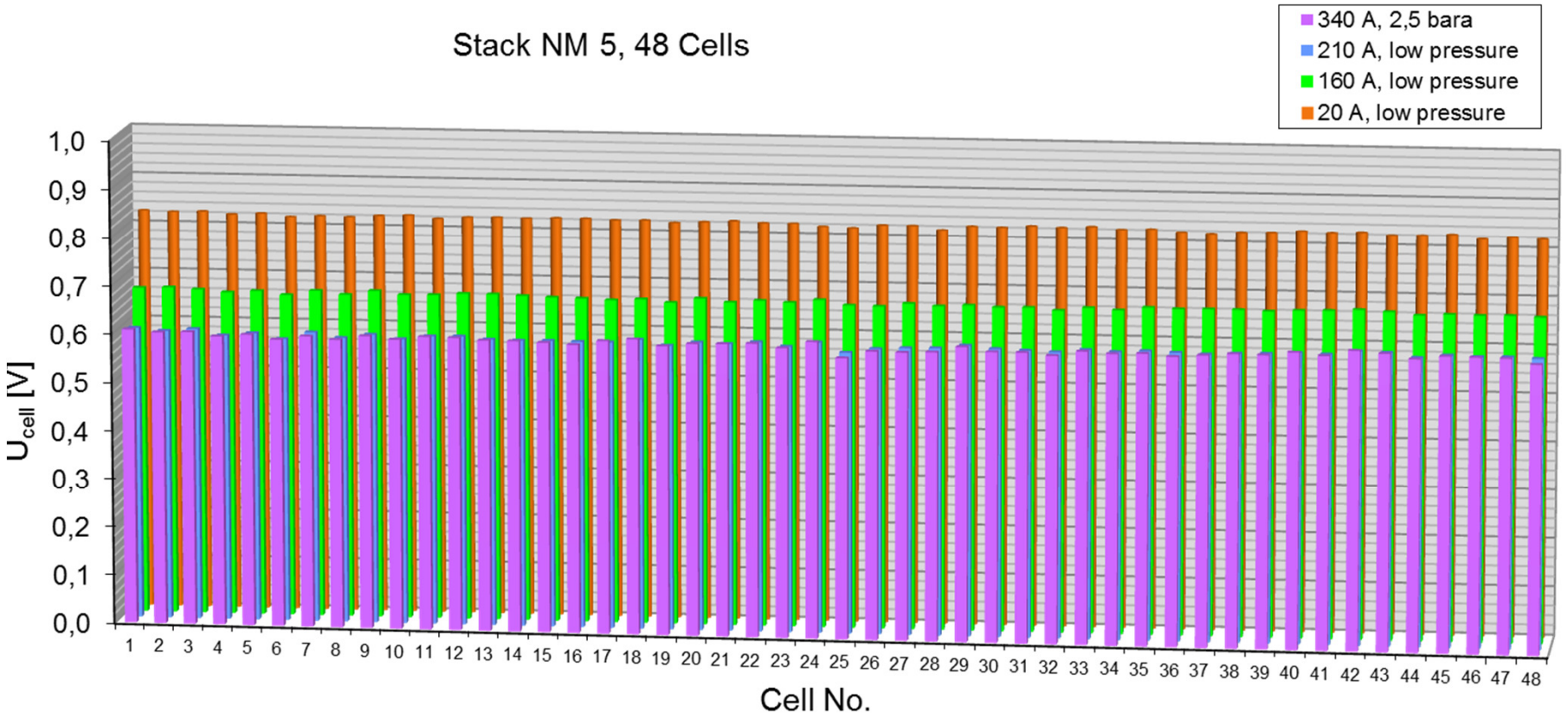
PEMFC-Stack NM 5

Performance and pressure drop cathode NM 5



- $\Delta p_{cathode}$ < 130 mbar, cathode NM5 at full load (low pressure operation) has almost same pressure drop as cathode NG 3

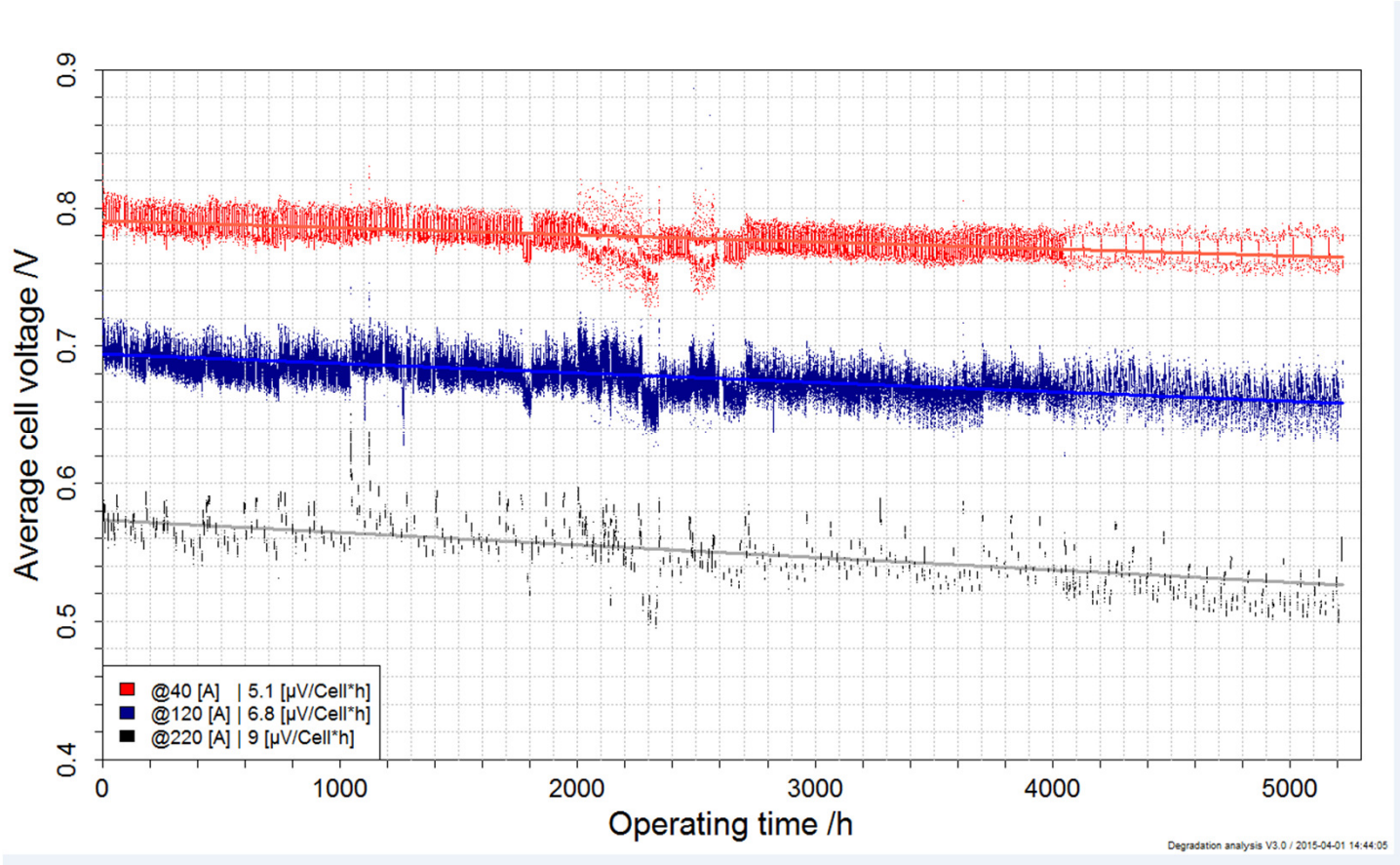
PEMFC-Stack NM 5 - Performance



- Homogeneous cell voltage distribution over the whole load range and at different operating conditions

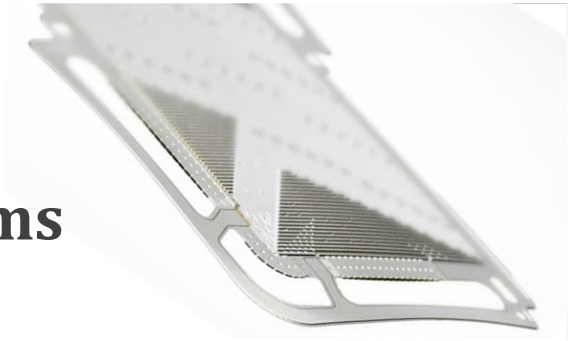
PEMFC-Stack NM 5

Lifetime test, low-pressure stack operation (test ongoing, > 5500 h)



- Degradation rate : 6-9µV/h at different load levels (40/120/220 A)

Metallic bipolar plates – potential problems



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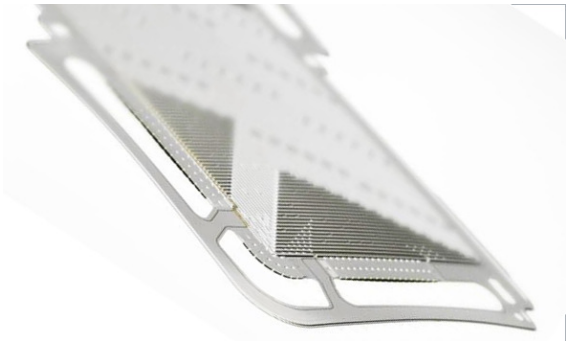
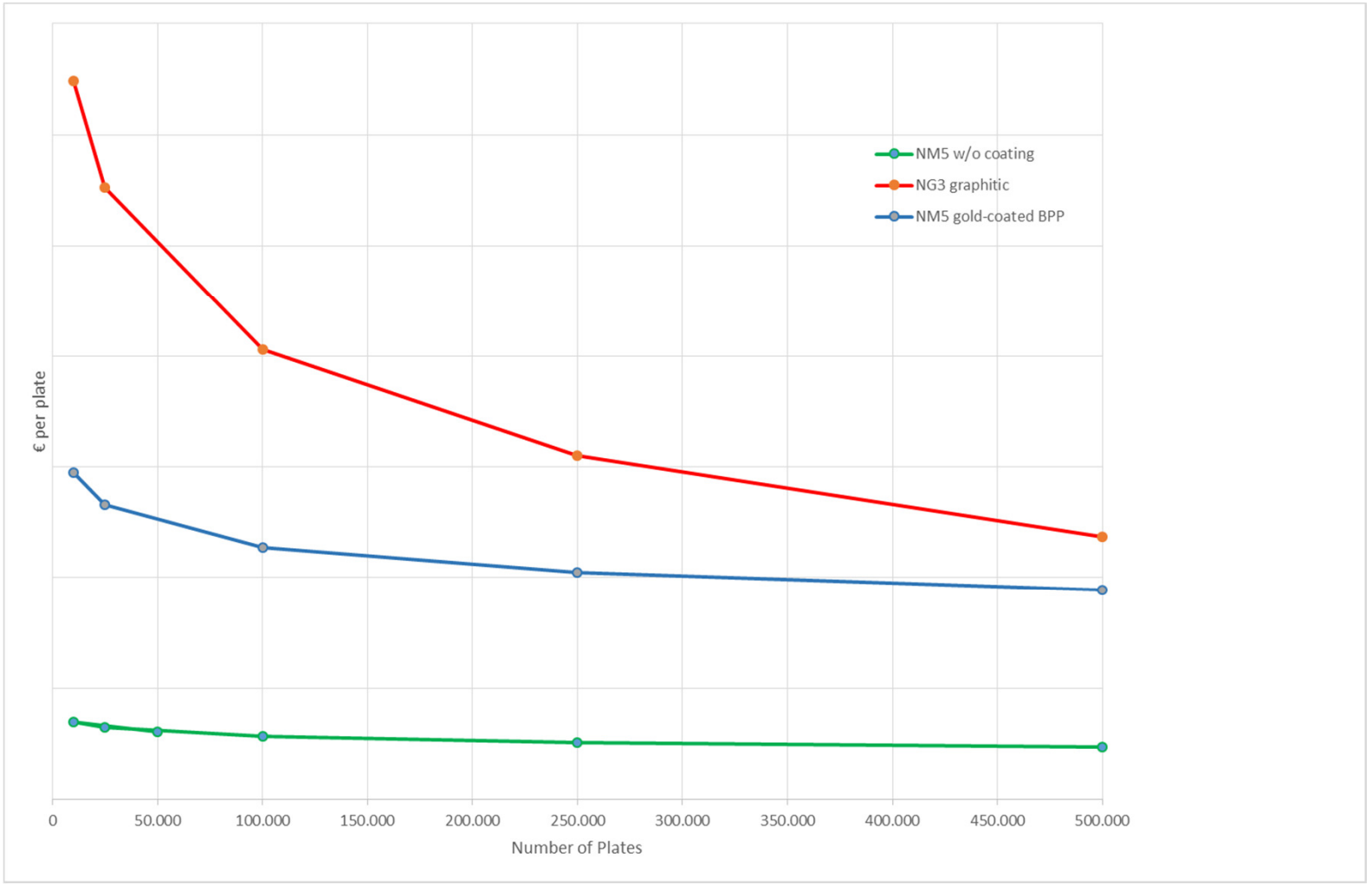
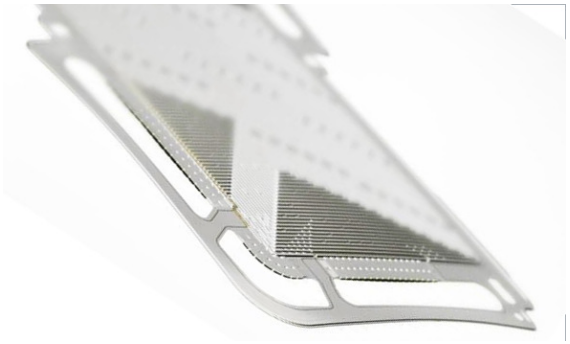
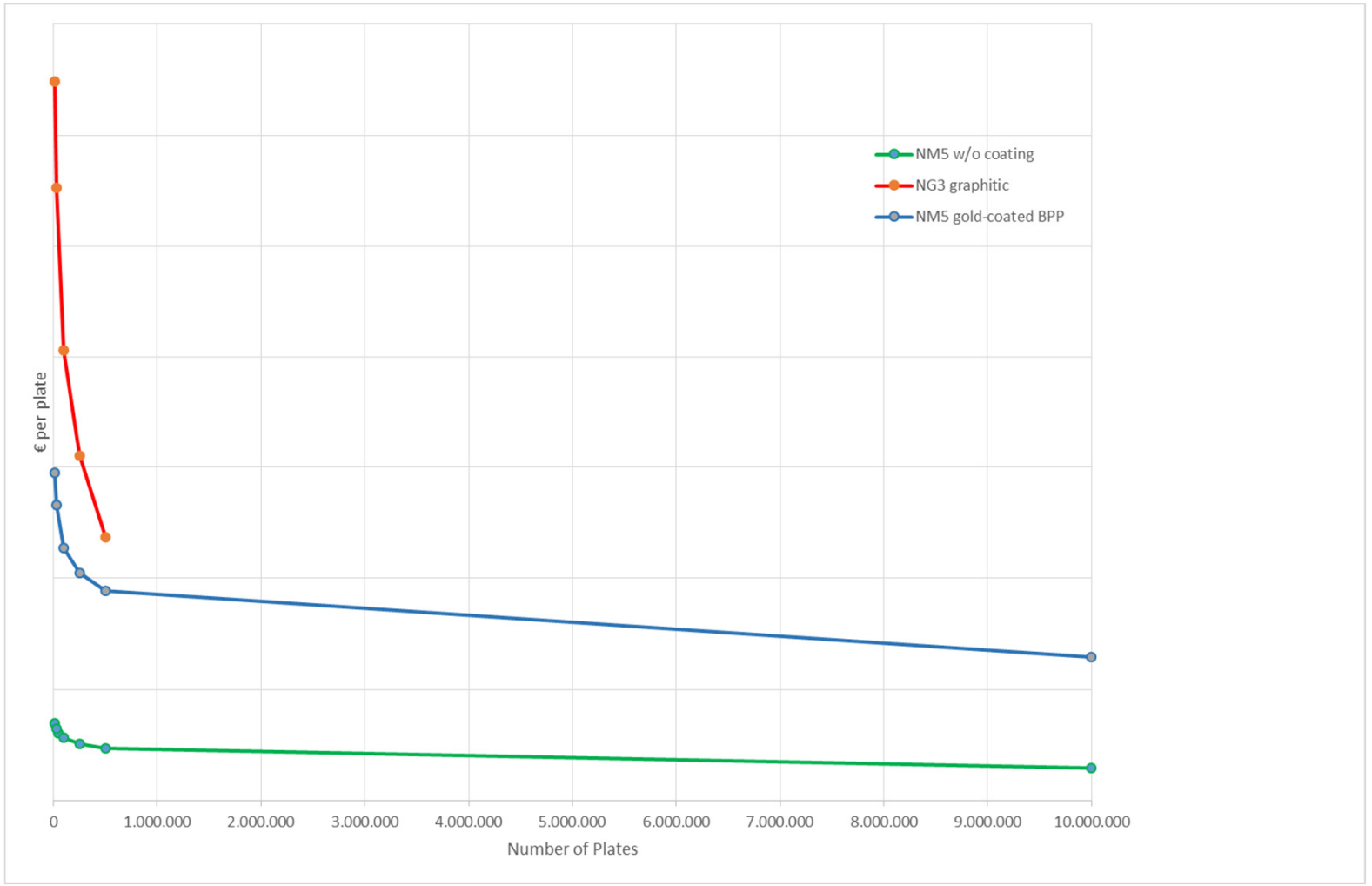
Bipolar plates – cost scenario



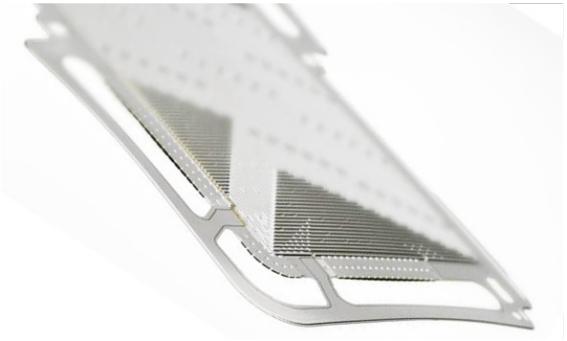


Bipolar plates – cost scenario





Bipolar plates – cost scenario

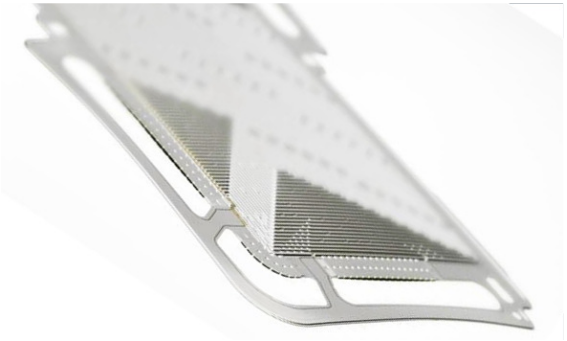


- Graphitic plates only viable when numbers are low or when extreme lifetime required

- Cost of metallic plates dominated by gold coating

- Also the process of gold application is very expensive

Bipolar plates – outlook



- Alternatives to the gold coating are needed!

- Emerging / under evaluation:

  - Pvd-coatings with low-cost materials (Sandvik, Impact coatings, Teer Coatings etc.)

  - “diluted” gold-coating (Treadstone)

  - Conductive spray or dip coating?

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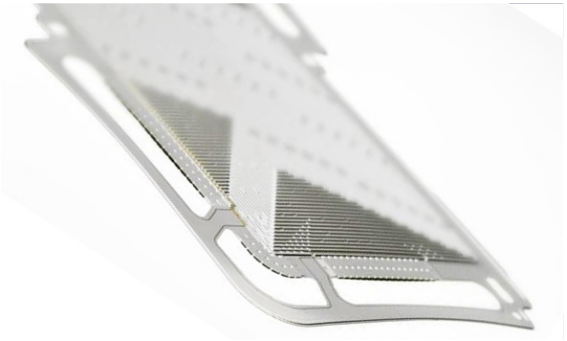
Summary



- Bipolar plate production is ready for industrialization

- Performance and lifetime proven for gold-coated bipolar plates in NM5

- Coating issue is still open –solution is crucial

- First markets where cost pressure is not too high – non-automotive applications can be realized with gold-coated bipolar plates

Thank you for your attention!

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+49-7123-724409

elringklinger

<u>ElringKlinger‘s PEMFC-Stack development is supported by:</u>