Zentrum für BrennstoffzellenTechnik
The fuel cell research center

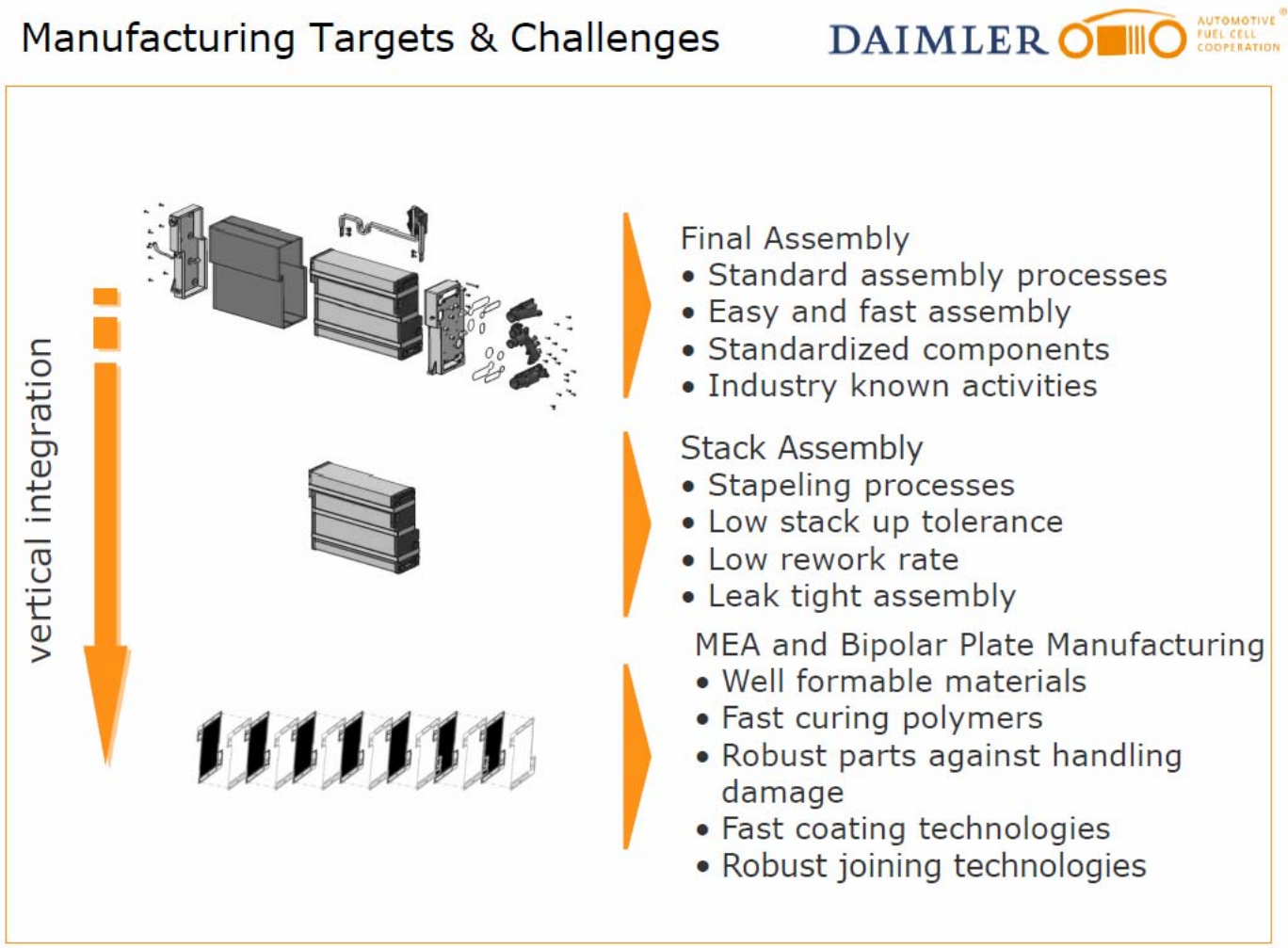
Production and automation for fuel cells and components

R&D supporting industrial processes

Dr.-Ing. Peter Beckhaus

Stuttgart, F-Cell, 08.10.2012

Development focus cost reduction: Manufacturing and assembly



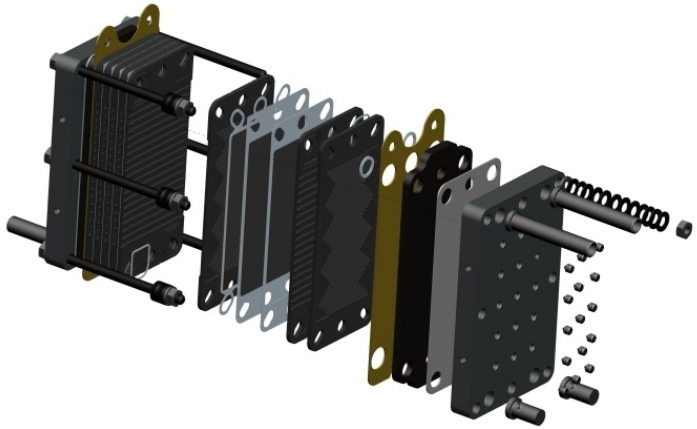
source: Dr. Dieter Steegmüller, Daimler, F-Cell 2011

Keywords:

- standard
- easy
- fast → cost
- robust → quality

Development focus cost reduction: Key factors for reliable fuel cell products

A fuel cell stack is built using 10^2 – 10^3 parts

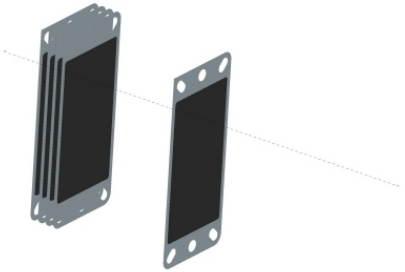


For market penetration of fuel cells in significant numbers standardised, easy, fast and robust production is essential, meaning:

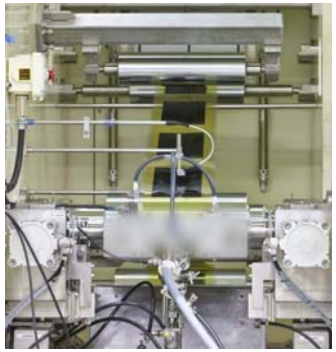
- High quality of the single component
- Reduction of the human influence factors
- Reaching reproducible pieces and products
- Including traceable parts
- Full documentation, verification
- Product Lifecycle Management
- Topics of recycling have still to be addressed

Component production: Membranes, GDL, MEA

- Catalysts layer is printed on GDL or membrane
- hot pressing / bonding / laminating of GDL and membrane is standard
- sub-gaskets are standard for series products
- sub-gaskets help optimising automation and increase life time of fuel cell stacks
- Roll to roll processes are established at MEA manufacturer sites worldwide



source: Coatema Machinery GmbH



source: Honda 2010 (T. Brachmann / Hysys)

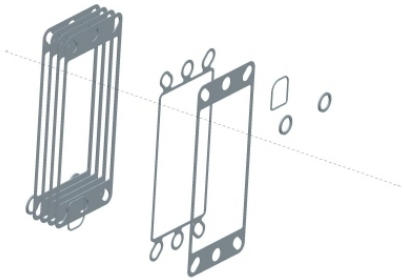
source: 3M Deutschland GmbH USA, 2011

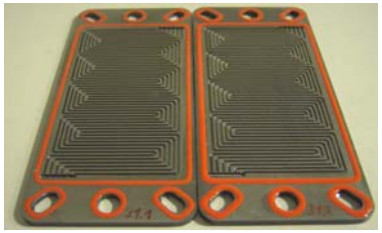
source: Youtube / Ballard PowerSystems (Ballard, 2012)

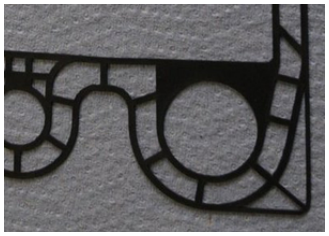
source: Youtube / ProvinceofBC (Mercedes / Burnaby 2012)

Component production: Gaskets

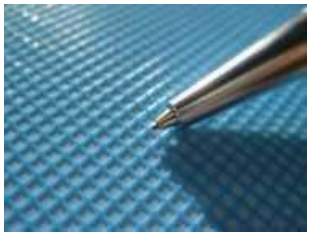
- Gaskets are necessary on MEA side, cooling side and at the media connectors
- Most crucial is the sealing at the MEA:
  - Gasket as part of MEA (Freudenberg Fast GDL, 9 layer MEA etc.)
  - gasket on bipolar plate (printing, dispensing, injection moulding)





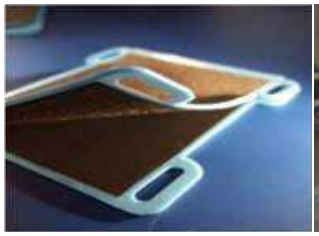


Laser cutted sheet:
ZBT GmbH



ICE-Cube sheet
Freudenberg FCCT

Integrated sealing
Freudenberg FCCT



Fast GDL
Freudenberg FCCT

Dispensing
ZBT

printing
Fix / ZBT

Component qualification: Gaskets

Batch wise

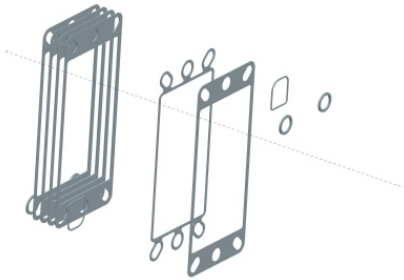
- chemical stability of material
- material leaching of components
- adhesion

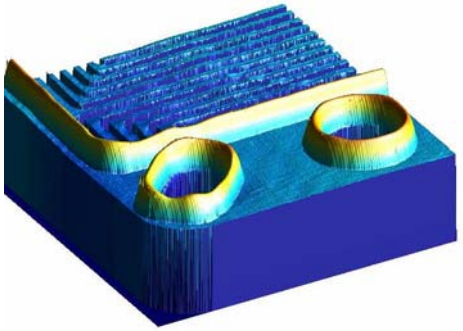
During processing

- viscosity
- supervising contour

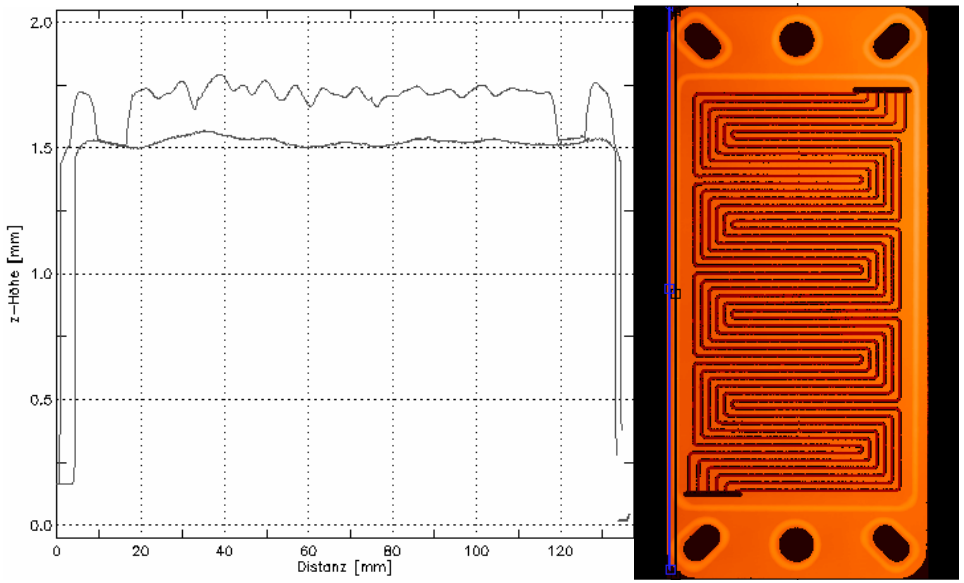
After processing

- form, geometry, placement
- height, tolerances





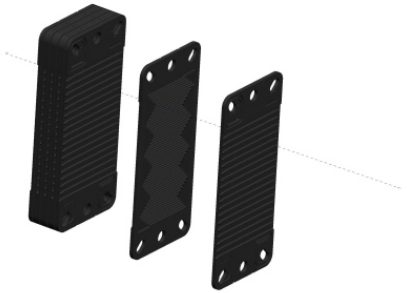
offline 3D analysis

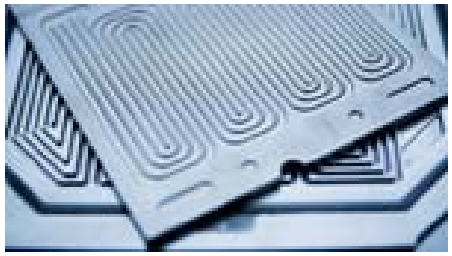


Line scan: quick check of geometry

Component production: Bipolar Plates

- bipolar plates are the mechanical cell frames and the main media carrier
- Two main technologies: metal or compound plates
- Compound plate production:
  - hot pressing
  - rolling
  - milling
  - injection moulding





source: Schunk

source: Dana

source: GrafTech

source: Eisenhuth

source: ZBT

Bipolar Plate Production
Example: injection moulding and necessary quality testing

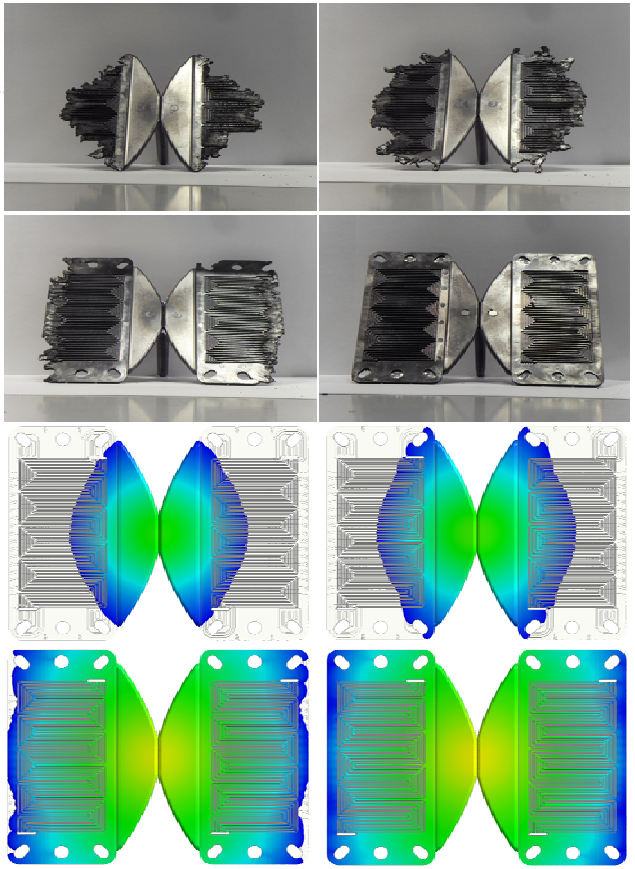
Gefördert durch:
Bundesministerium für Wirtschaft und Technologie
aufgrund eines Beschlusses des Deutschen Bundestages

Significant parameters influencing the quality of the bipolar plate are:

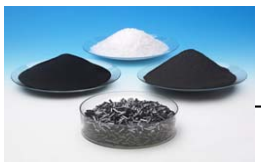
- material
- cooling time
- injection volume flow
- ejection speed
- temperature of form

Inline quality observation by

- analysis of machine & process parameters
- article analysis



Source: IPE/ Uni DUE

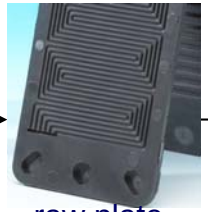


graphite, CB, polymer

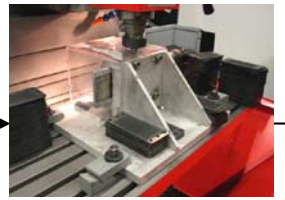
extrusion

compound

injection moulding



raw plate



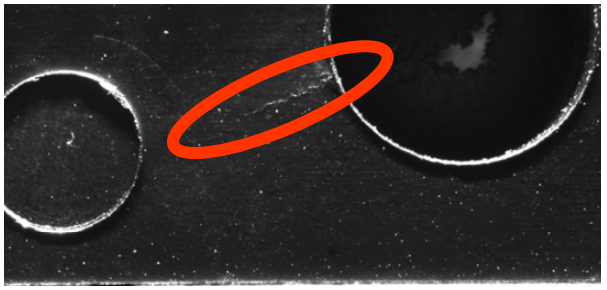
final treatment

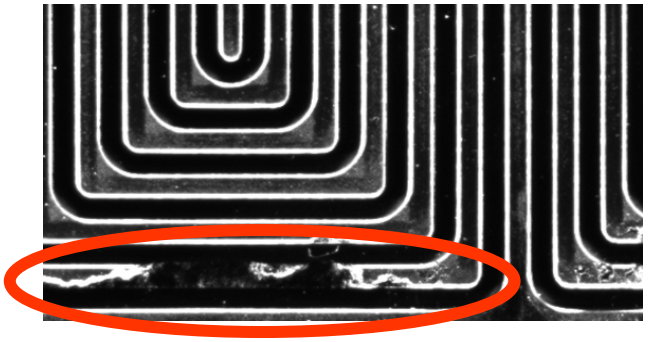
bipolar plates

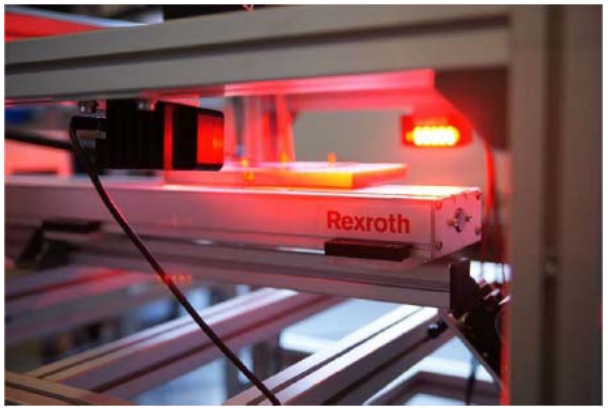
Quality assurance inline to the production process example bipolar plate

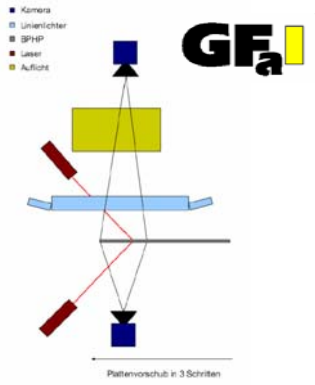
Gefördert durch:
Bundesministerium für Wirtschaft und Technologie
aufgrund eines Beschlusses des Deutschen Bundestages

- optical fault detection allows contact-free analysis of components
- reflexions caused by lateral side / dark field illumination → surface quality and hair cracks
- laser line illumination → thickness profiles
- quality characteristics:
  - sprue brim
  - overall dimensions, thickness, planarity/parallelism
  - flow field structure
  - burrs, capillary cracks
  - groove depths
- fast and secure process (Cycle time 4,3 sec.)
- 100 % testing is possible

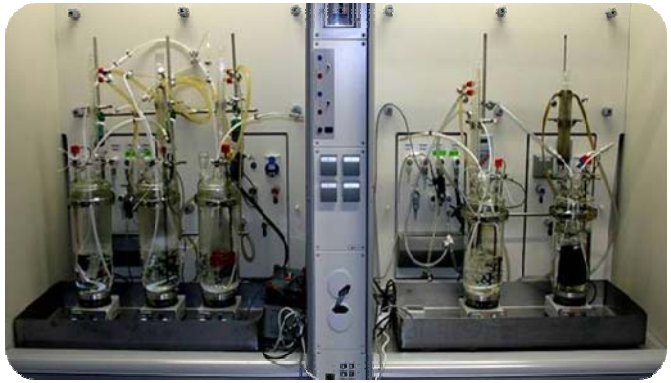


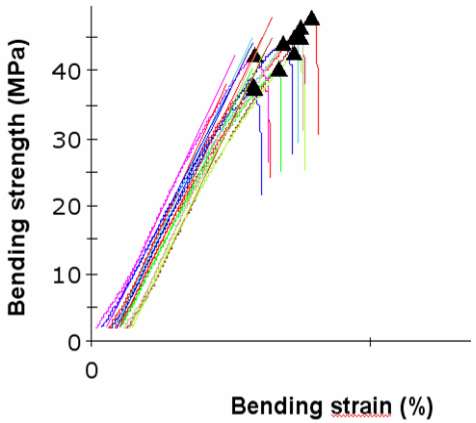






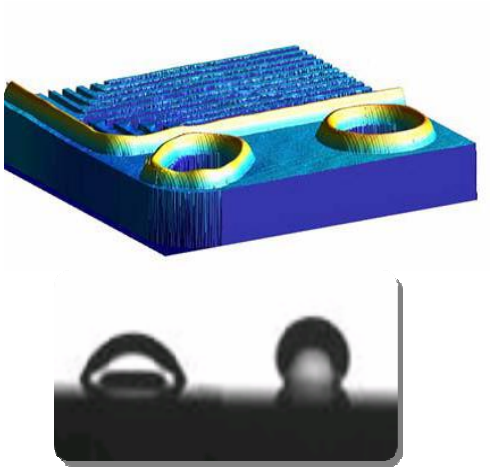
Quality assurance batchwise in parallel to the production process example bipolar plate & gaskets



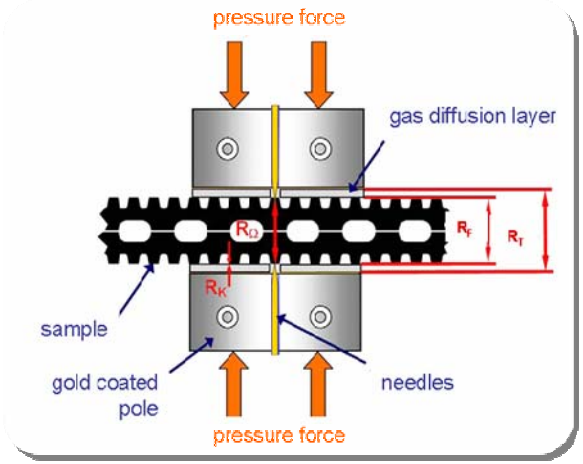


Ex-situ accelerated ageing (H_2SO_4 @80°C or H_3PO_4 c=85% @ 180 °C)

Mechanical testing



Surface properties



Electrical characterization

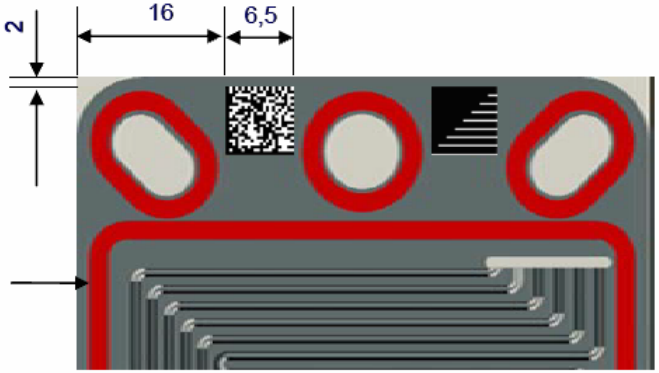
Permeability testing

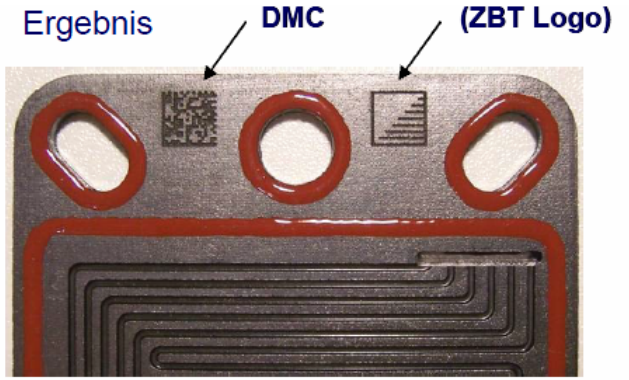
Traceablity
example bipolar plate

Gefördert durch: Bundesministerium für Wirtschaft und Technologie aufgrund eines Beschlusses des Deutschen Bundestages
ZIM impulse für wachstum Zentrales Innovationsprogramm Mittelstand

SITEC

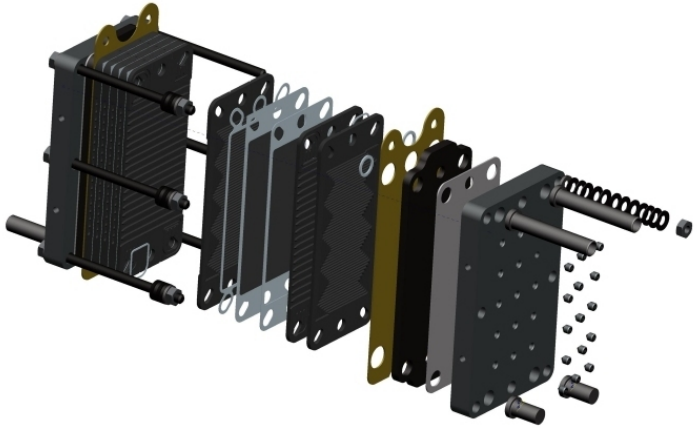
- Traceability refers to the completeness of the information about every step in a supply chain
- **Step 1:** Recording of any relevant process and material data
- Data base structure and route cards are essential
- For feedback and for analysis of fault causes in the final product clear production numbers are essential
- **Step 2:** Marking / signing of components
  Data Matrix Code or Real Numbers / Text





Stack production
Cell and Stack assembly

- Stacking of cell components
  - MEA
  - Gaskets
  - Bipolar plates / halfplates
- End-Plate Integration
- Compression / Fixing
- Approval



source:
KuKa / ZSW ~2007

source: Honda 2010

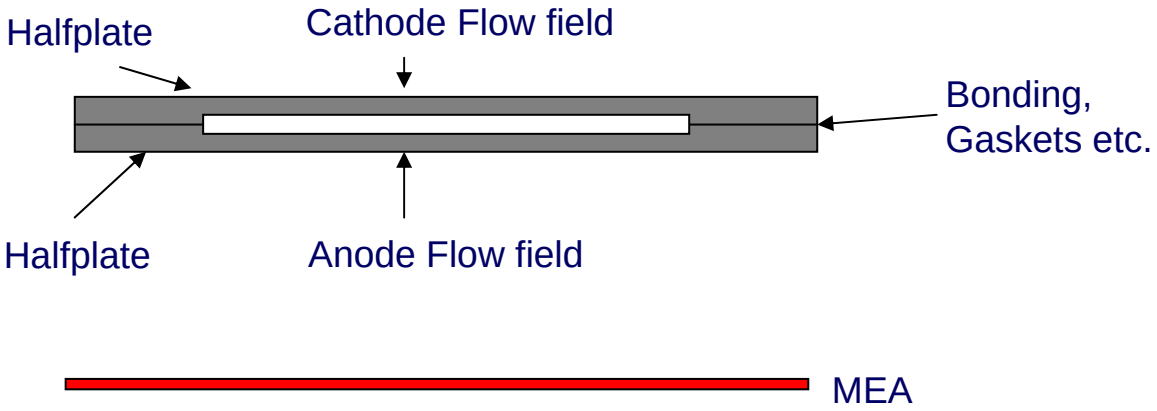
FIX / ZBT 2011

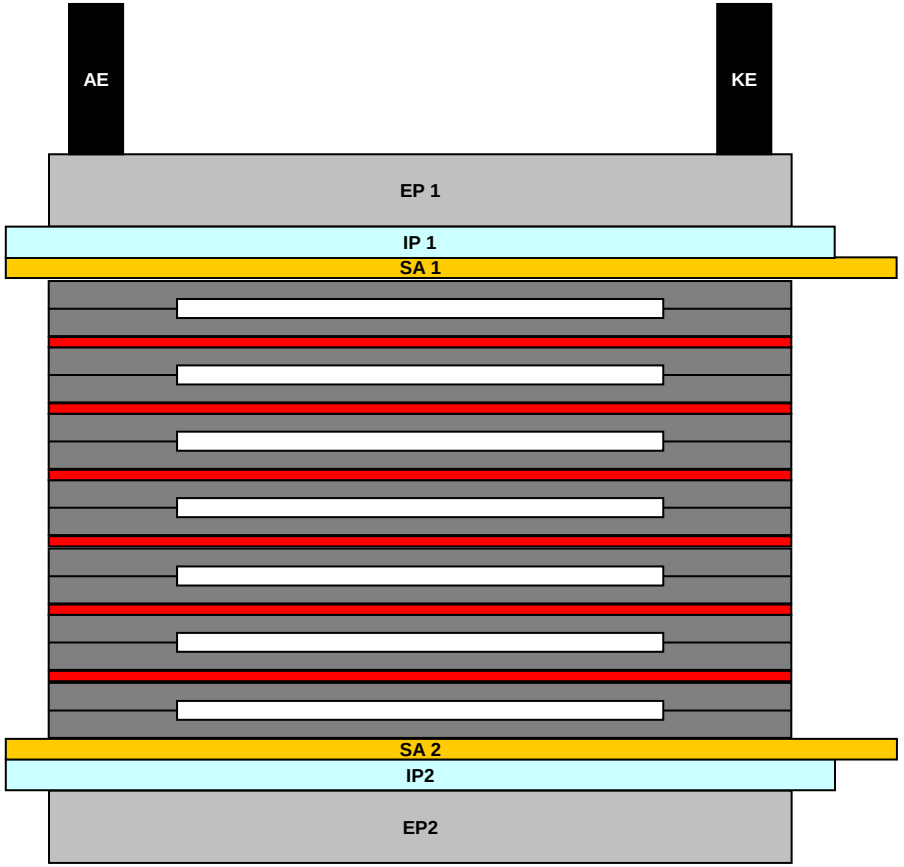
source: Youtube /
ProvinceofBC 2012

source: Youtube /
BallardPowerSystems 2012

Assembly of Stacks dependenant from bipolar plate technology

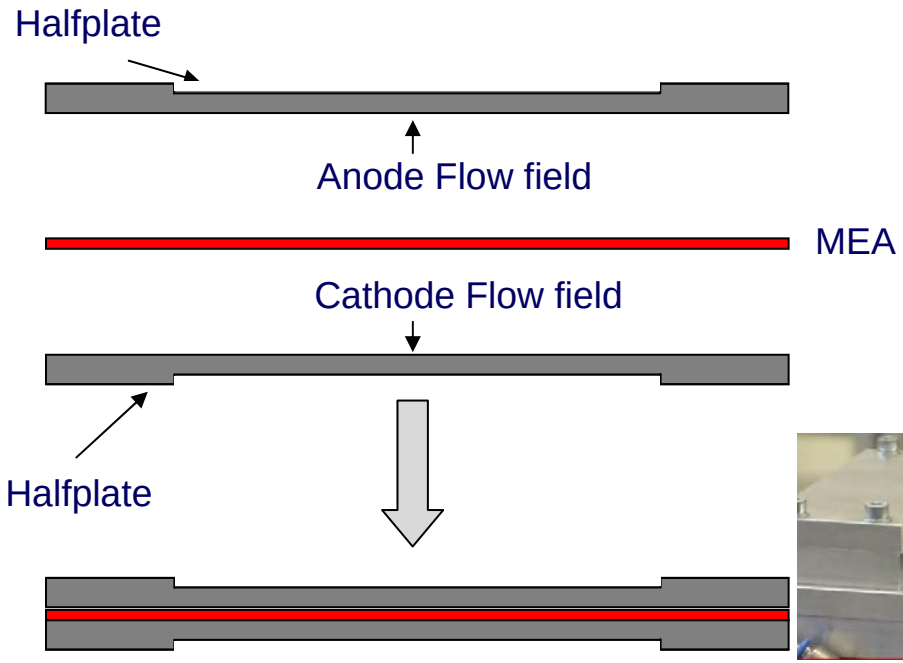
- Option 1: A bipolar plate having anode gas channels on one side and cathode gas channels on the other side
  - usually with metal foil plates (welded)
  - bonded half plates
  - real bipolar plates without cooling
- Components Plate, Gaskets, MEA have to be stacked individually
- Handling of MEA and pliable parts is difficult



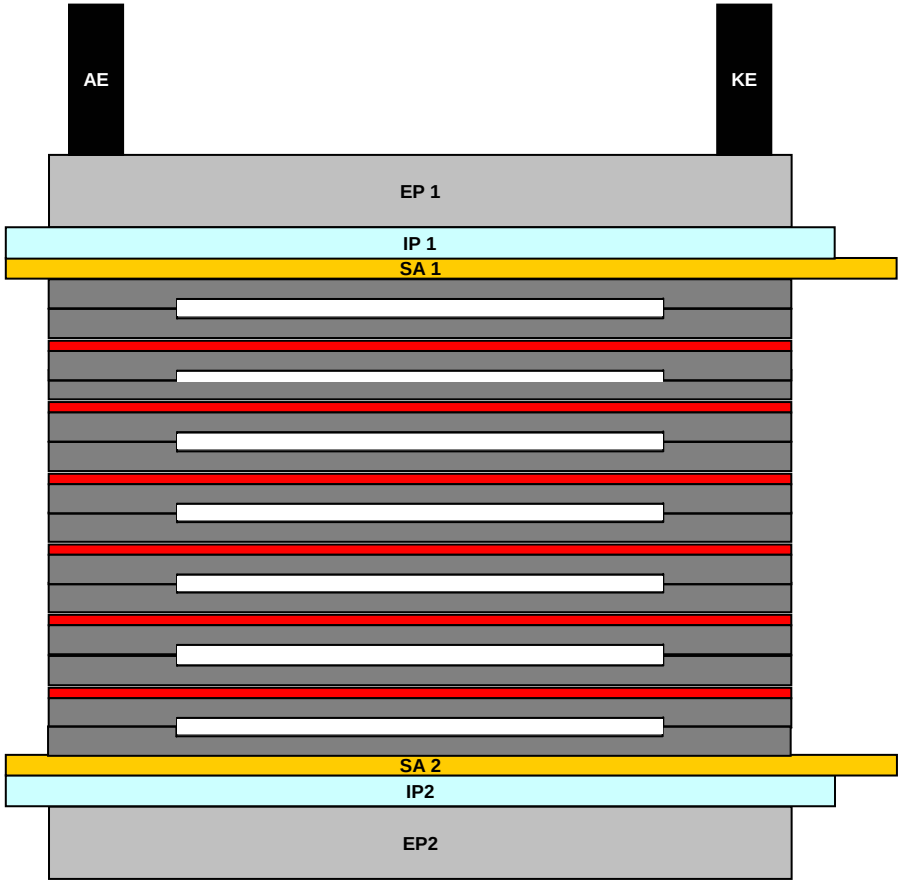


Assembly of Stacks dependenant from bipolar plate technology

- Option 2: Two Halfplates form one single cell
- Advantages:
  - The cell can be riveted / fixed
  - The cell can be tested individually regarding leakage
  - Stack assembly manual possible

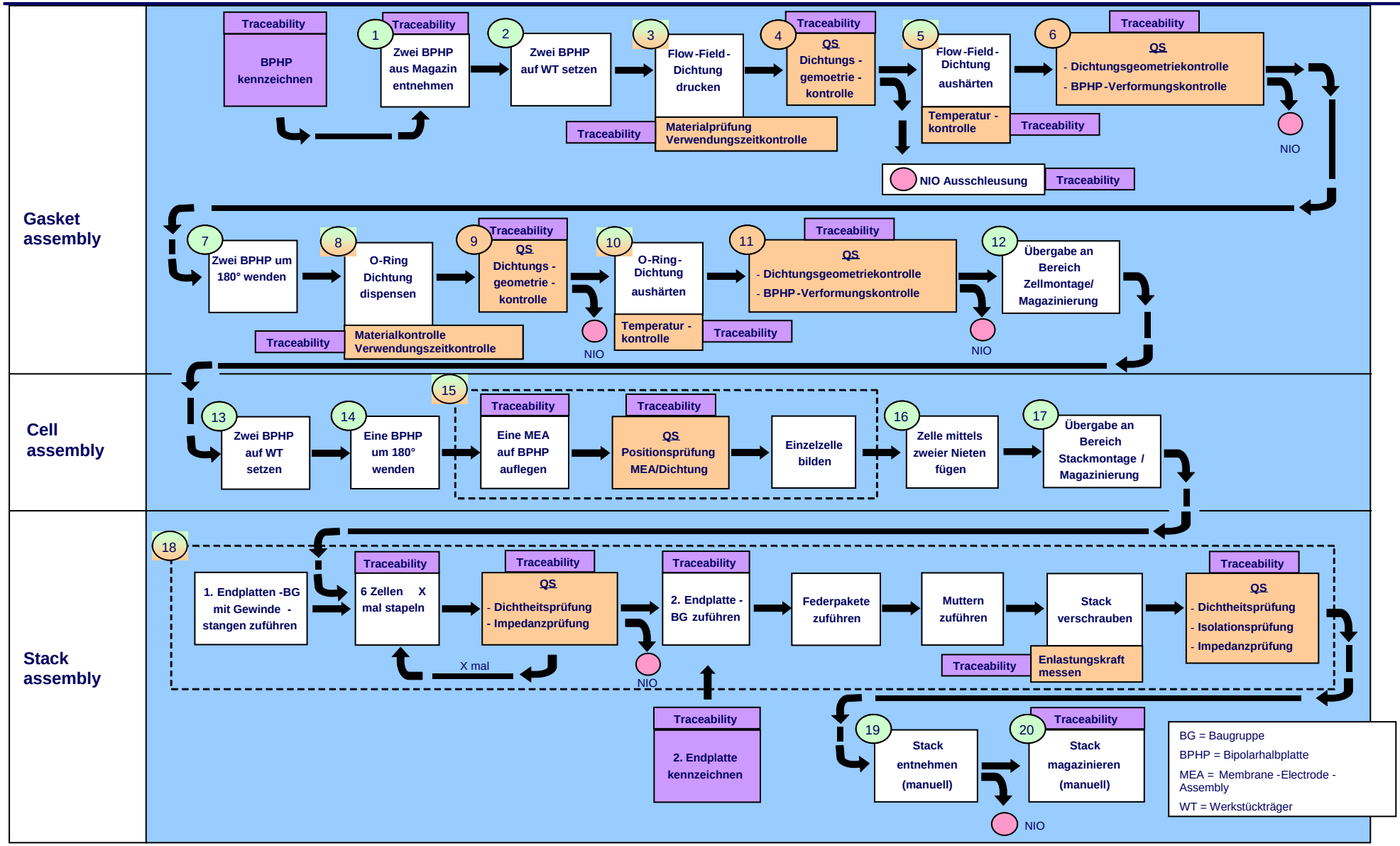


rivetting single cell



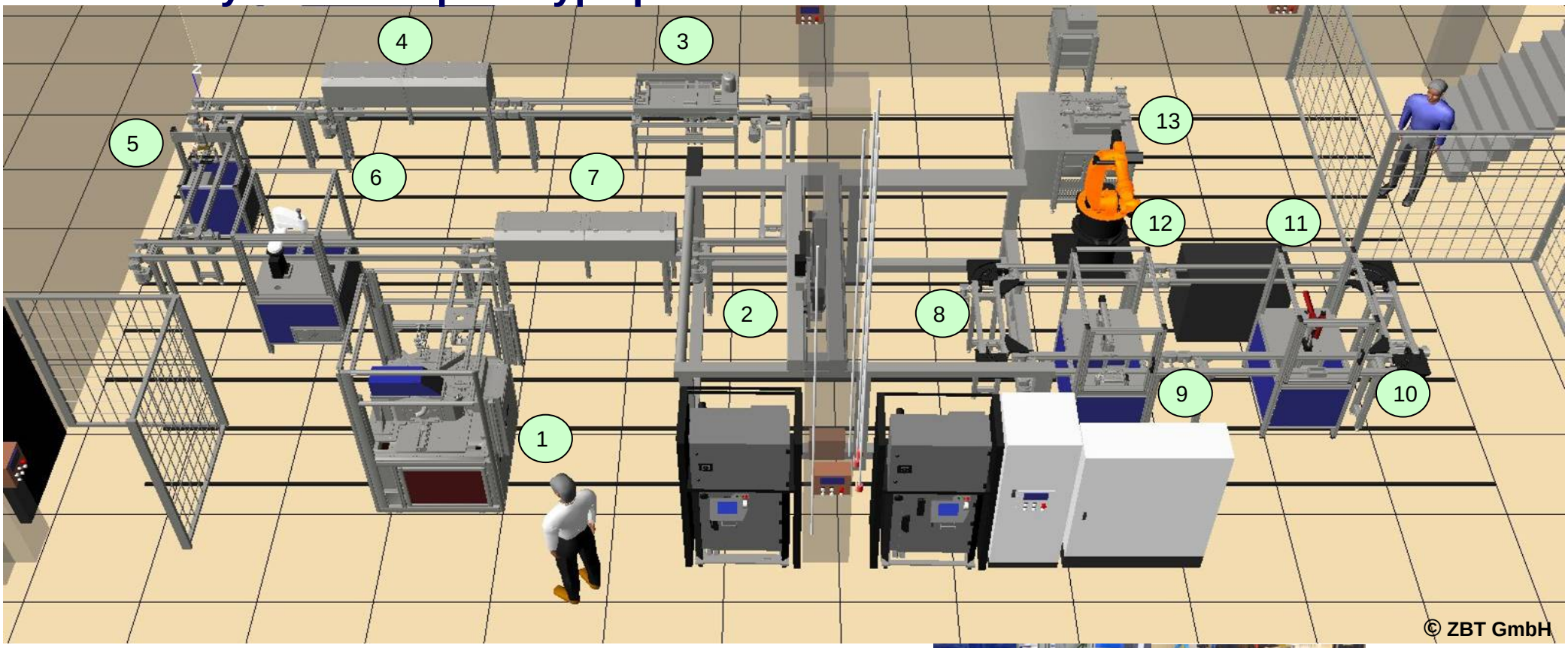
Assembly of Stacks

Traceability and quality testing in production process

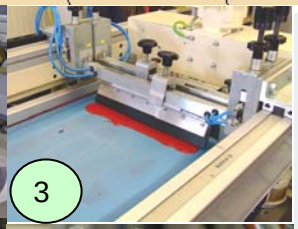


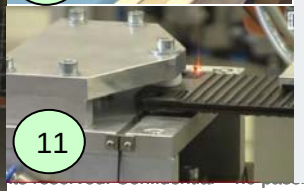
ZBT production technology development: Layout of the prototype production line at ZBT

Gefördert durch: Bundesministerium für Wirtschaft und Technologie aufgrund eines Beschlusses des Deutschen Bundestages
ZIM impulse für wachstum Zentrales Innovationsprogramm Mittelstand



1. Bipolarplatten kennzeichnen
2. Ein- und Ausschleusung Bipolarplatten
3. Flow-Field-Dichtung drucken
4. Flow-Field-Dichtung aushärten
5. 2 Bipolarplatten wenden
6. O-Ring-Dichtung dispensen
7. O-Ring-Dichtung aushärten
8. Übergabe und Einschleusen Bereich Zellmontage
9. 1 Bipolarplatte wenden
10. Auflegen einer MEA und Bilden einer Zelle
11. Zelle zu einer Einheit fügen
12. Übergabe an Bereich Stackmontage/ Magazinierung
13. Montage und Prüfung des Stacks





UTZ GRUPPE FIX Maschinenbau GmbH

Summary
and cooperation offer

- Automated production is a key factor for quality in fuel cell production
- Only at significant numbers it is also a cost factor
- Inline process control and traceability concepts ensure production quality
- Different steps of component and stack production have been demonstrated and are available for industrial use
- ZBT as R&D provider is able to assist on production analysis
- Prototype production line to develop production processes for automated series production is available
- Main targets are ***low cost production, high quality, repeatability and traceability***

Zentrum für BrennstoffzellenTechnik (ZBT) GmbH

Thanks to ZBT staff, especially:

Thorsten Derieth, Marco Grundler, Sebastian Brokamp, Patrick Butzen, Tobias Grimm, Matthias Heina, Lars Preißner

Our partners in the projects:

Gesellschaft zur Förderung der Angewandten Mathematik

University of Duisburg-Essen, Prof. Witt and Prof. Wortberg

SITEC Industrietechnologie GmbH

Fix Maschinenbau GmbH

Thanks to the **BMWi** for supporting the **IGF** projects 16041N (01.04.2009 - 31.12.2011), 304 ZN (01.01.2009 - 28.02.2011) 16072 BG (01.05.2009 - 31.07.2011) and for supporting the **ZIM** projects 2056303PK9 (01.04.2009 - 31.08.2011) and 2056305DA9 (01.01.2010 - 30.09.2011)

Ziel2.NRW
Regionale Wettbewerbsfähigkeit und Beschäftigung

Gefördert durch:
Bundesministerium für Wirtschaft und Technologie
aufgrund eines Beschlusses des Deutschen Bundestages