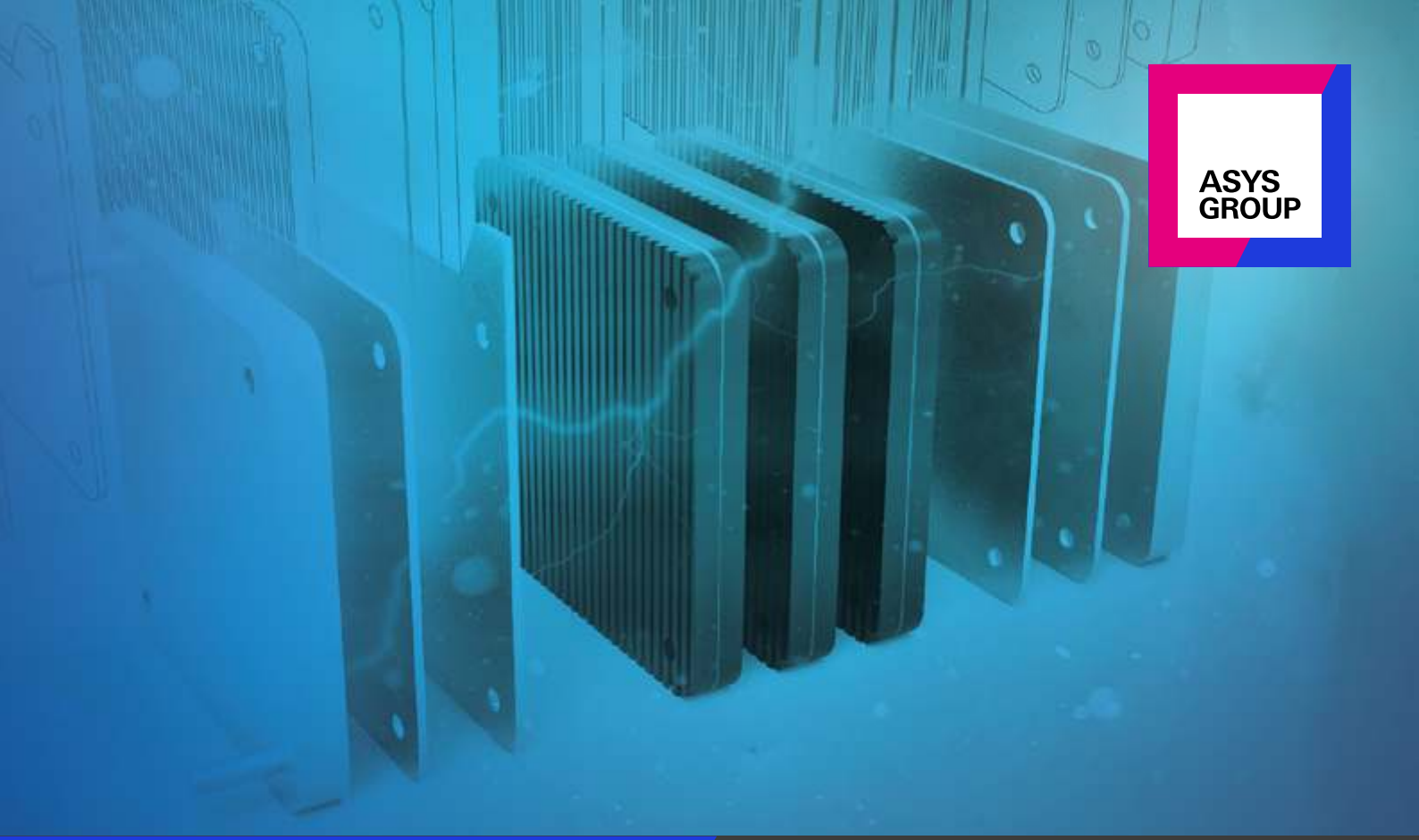

ASYS GROUP

ASYS Group Energy

Turnkey Solutions for Fuel Cell Production

ASYS Group

Transforming Ideas Automate, Digitalize & Connect

The ASYS Group is a globally active technology company and leading supplier of standard and special systems for the business fields of electronics, energy and life science.

ASYS Automatisierungssysteme GmbH is the lead company of the group. With over 1,500 employees worldwide, the ASYS Group develops, manufactures and markets high-quality and innovative automation solutions. It has a global sales network with local contacts in more than 40 countries. 20 subsidiaries in Europe, Asia and America enable customer-oriented support.

ASYS Group can offer its customers comprehensive solutions from a single source and undertakes development at various sites, which are connected by a strong network for technology transfer between research and development departments.

ASYS Group – Energy

Turnkey Solutions for Fuel Cell Production

For more than a decade, the ASYS Group has been successfully developing and building manufacturing solutions for the Energy business unit. The solar industry has played a key role in its success story by delivering hundreds of metallization back-end lines worldwide to this date. Therefore, the ASYS Group is one of the pioneers which helped to initiate the volume production of renewable energies.

One of the key processes within such a high volume production line is applying structures onto substrates by means of screen printing on both sides. The current system generation achieves a production capacity of more than 7,200 cells per hour with a dual lane configuration at highest precision in the industry. Screen printing as an established coating technology is also a key process in manufacturing of polymer electrolyte membrane (PEM) fuel cells and solid oxide fuel cells (SOFC). Besides this important technology, the ASYS Energy business unit offers complete turnkey solutions for high volume production in the field of renewable energies, e.g., solar cells, fuel cells and batteries.

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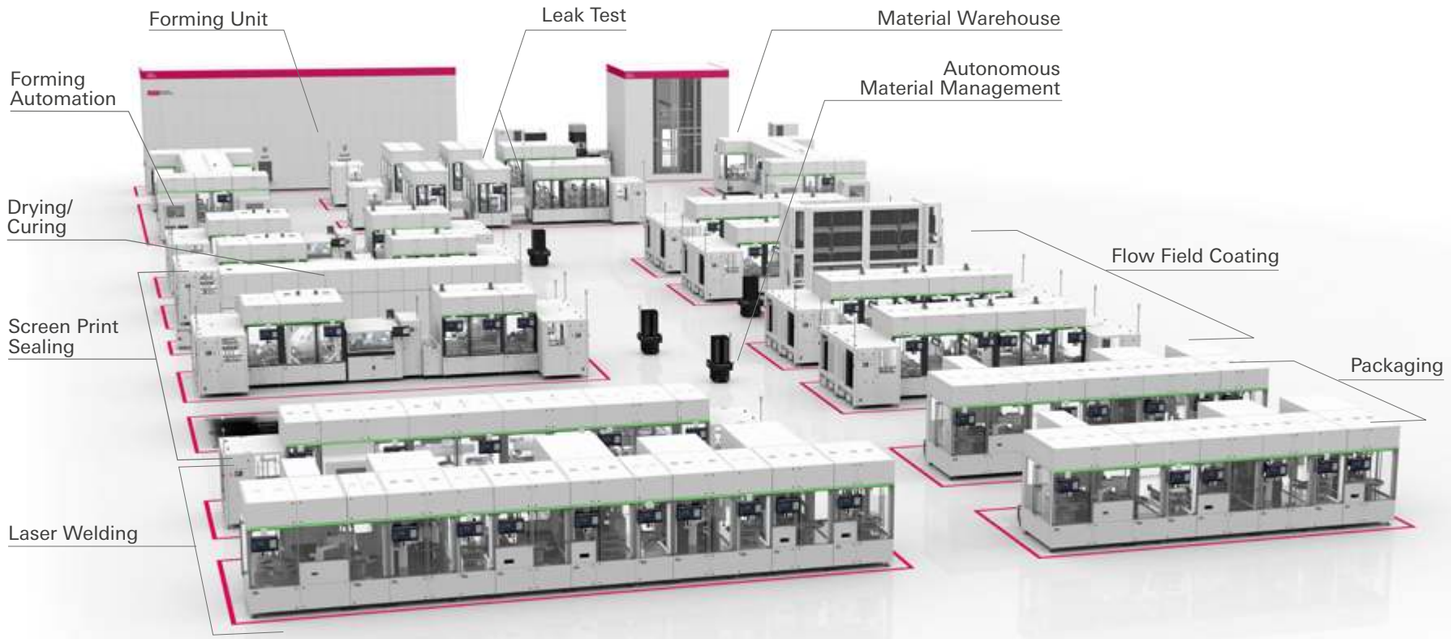
SOFC/SOEC

PEMFC

Efficient Fuel Cell Volume Production with ASYS Group Turnkey Solutions



Our turnkey solution for high volume production of fuel cells combines a large number of individual manufacturing processes. This complex interaction of diverse requirements is monitored and coordinated on system level via our PULSE PRO software. In addition, our Material Logistics solutions offer an automated and smart material flow through the entire production by buffering materials close to production level.

Our know-how includes the high-precision printing of different, very thin and fragile substrates. These are requirements, we also face for manufacturing of fuel cell membranes. The EKRA printer portfolio ranges from stand-alone systems to one second high-speed lines.

For welding of metallic bipolar plates, we use solutions from the POLYPHOS product line. Further laser processes include laser direct marking of bipolar plates and ceramic membranes and burr-free cutting of ceramic membranes for SOFC / SOEC applications.

Our INVENTUS product line is designed to develop and implement sophisticated automation tasks such as those required for stack assembly. Furthermore, we offer individual control options to monitor the paste application of the membrane or the sealing pressure of the bipolar plate. The result of this broad range of services are innovative manufacturing and assembly concepts for your fuel cell production.

We are happy to support you with entry-level to high volume scenarios.

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SOFC / SOEC Technology

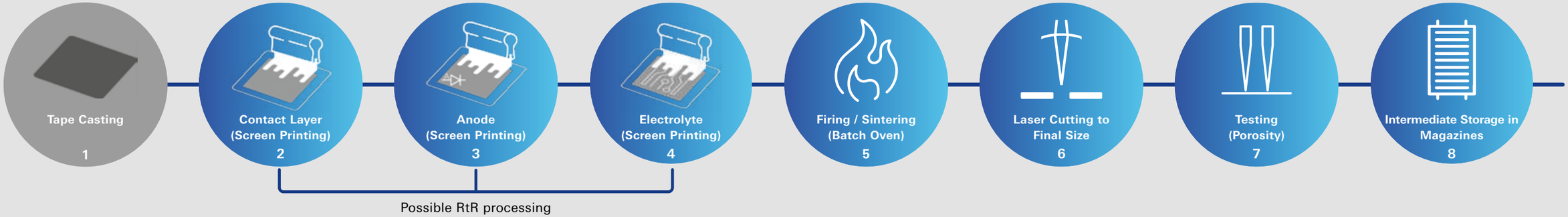
A Solid Oxide Fuel Cell (SOFC) operates at high temperatures, typically between 600 °C and 1000 °C, which allows for efficient ion transport and electrochemical reactions. The key components of a SOFC include the anode, cathode, electrolyte, and interconnect.
The anode is typically made of a porous ceramic material, often based on a mixed metal oxide, that allows the passage of fuel gas, usually hydrogen or a hydrocarbon like methane. Here, a reaction occurs that generates electrons and oxygen ions. The electrons are then conducted through an external circuit, creating an electric current that can be used to perform work.

The electrolyte is a ceramic material known for its high oxygen ion conductivity. It serves the purpose of separating the anode and cathode compartments while facilitating the movement of oxygen ions from the cathode to the anode. This ion transport is critical for maintaining charge balance within the cell.

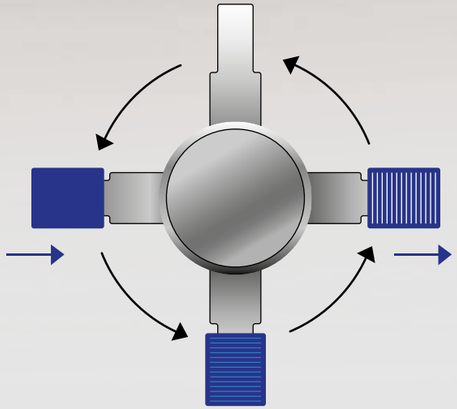
The cathode is also composed of a porous ceramic material, frequently incorporating perovskite oxides or comparable compounds. In this region, oxygen from the surrounding air engages with the oxygen ions conveyed through the electrolyte, culminating in the formation of oxide ions. Subsequently, these oxide ions traverse the electrolyte, moving towards the anode.

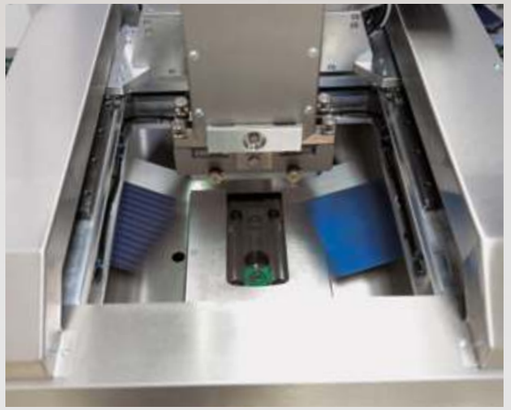
The elevated operational temperature of SOFCs offers advantages, enabling swift ion transport and reducing the necessity for costly catalysts. Nonetheless, it also presents challenges concerning thermal management and start-up duration. Given their efficiency, minimal emissions, and fuel adaptability, SOFCs find diverse applications such as stationary power generation and auxiliary power units for vehicles.

ASYS Group Process Steps



Screen Printing Technology





In the anode-based concept, an oxide ceramic acts as the substrate for the SOFC. ASYS offers processing solutions for this concept, catering to both fired and unfired states of the ceramic. The materials used can be easily transformed into a paste form, facilitating the application of all active elements and supporting layers through screen printing.

By utilizing optimized screen meshes and process parameters for each step, a wide variety of materials can be applied using an EKRA printing machine. This ensures precise and uniform deposition of the required layer thicknesses. These achievements are realized at remarkable production speeds, with cycle times as short as 1.2 seconds per sheet using our AIRON product line.

The AIRON printing line sets the benchmark for alignment repeatability in the market, boasting an impressive 12.5 µm with a print quality rated at 6 σ. The entire printing line is designed for optimal ergonomics and usability, ready to accommodate your evolving needs, whether that is adapting to new technological applications or expanding production lines.

Furthermore, all future technologies developed by the ASYS Group can be optionally integrated into a package with the AIRON product line, ensuring you stay at the forefront of advancements.

Technical Information:

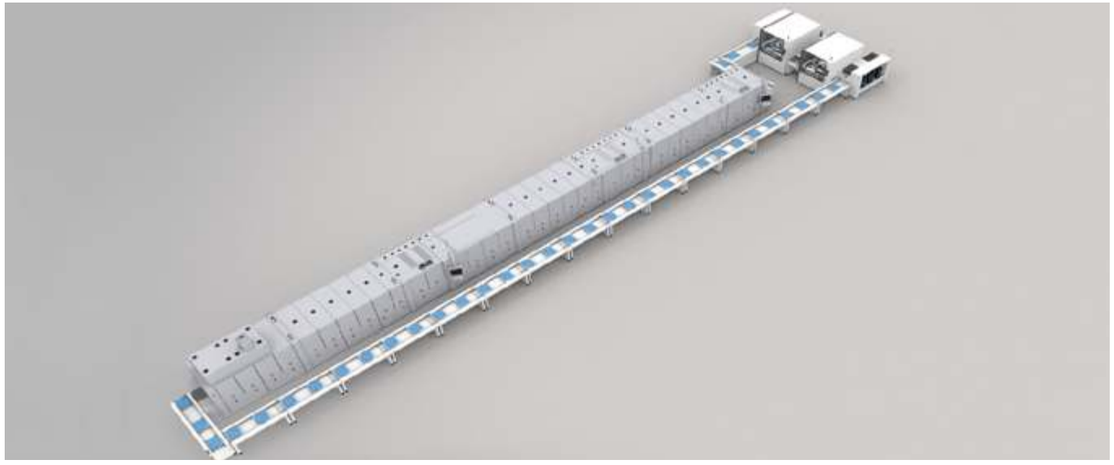
- Processing times of up to 3,000 substrates per hour per line (up to 6,000 substrates in dual lane configuration)
- Air spin paddle and print nest with soft paper cover for smooth handling of substrates of up to 210 x 210 mm size
- Flexible line configuration with high-speed loading and unloading systems with autonomy of up to 15 minuts at maximum throughput

Drying Technology

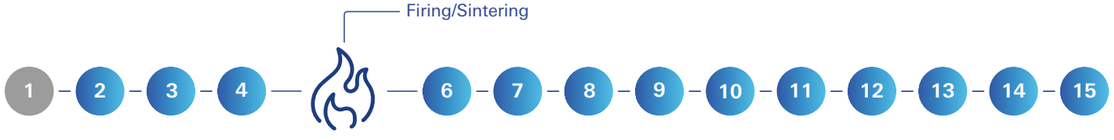
The ideal drying solution is determined and then integrated into the line concept. Drying can occur in magazine dryers, paternoster systems, or horizontal drying systems.

To safeguard the underlying substrate, the appropriate feeding technique involves magazine loading using knife-edge belts. For loading multiple substrates, parallel loading can be achieved even without a mechanical clamping device.

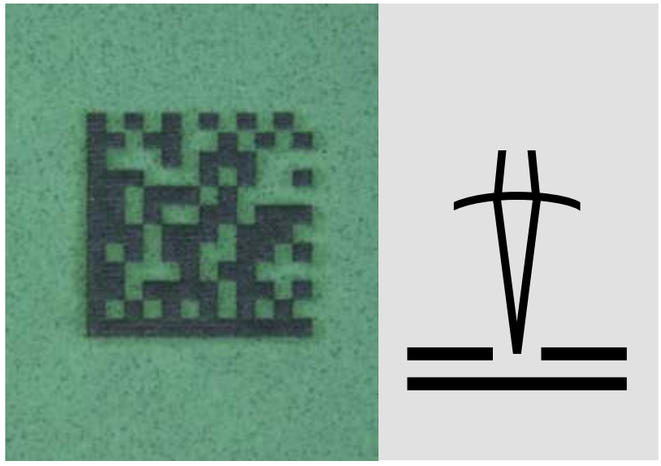
Automation Sintering Furnace



Sintering of the membrane at temperatures around 900 °C is performed using stand-alone or inline systems. To achieve this, the printed and dried substrates must be efficiently fed into the sintering oven, maintaining competitive cycle times. This efficiency is achieved through our innovative automation solutions. As the sintering step can span several days, substrate processing is carried out using temperature-stable racks or pre-placed firing plates.
Depending on the automation concept, the sintered substrates are temporarily stored in magazines for subsequent processing using the cutting laser.



Laser Cutting and Marking



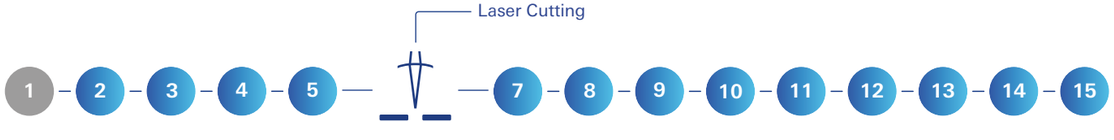
For the subsequent stacking process, it may be necessary to cut the ceramic substrates that have been sintered for the first time to their exact final size. Various laser systems from our POLYPHOS MM laser micromachining line are available for this purpose, depending on the required cycle time.

Additionally, POLYPHOS MK laser marking systems can be employed to imprint a DMC code (Data Matrix Code), enabling traceability after subsequent sintering processes.

The choice of the laser source is determined based on substrate-specific criteria in our laser laboratory

Technical Information:

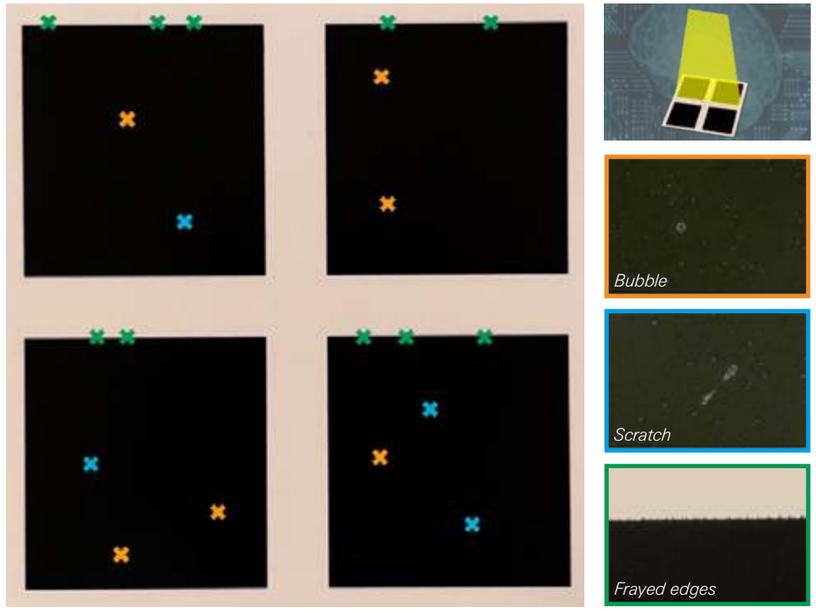
- Processing times for laser cutting of up to 180 substrates per hour per machine.
- Sufficient handling of substrates with sizes of up to 200 mm x 200 mm
- Use of various laser sources and optics



Testing (Porosity & Optical Inspection)

Quality control systems that ensure 100 % defect detection (such as pinholes and print misalignment) utilize 2D or 3D inspection technologies. ASYS provides its own systems that incorporate cutting-edge artificial intelligence (AI) technology for this purpose. Additionally, upon request, third-party systems can be seamlessly integrated into our comprehensive turnkey solution. Our systems encompass defect identification, dimensional analysis of printed structures, automated decision-making, advanced data visualization, and autonomous process optimization.

Particularly in the manufacturing of SOFCs with printed layers, porosity becomes a critical factor impacting performance and efficiency. The extent of porosity within materials influences aspects like gas diffusion, heat transfer, and chemical reactions within the cell. Our system guarantees 100 % quality control, ensuring the highest production yields.



An example of how print layers are analyzed using AI powered print inspection

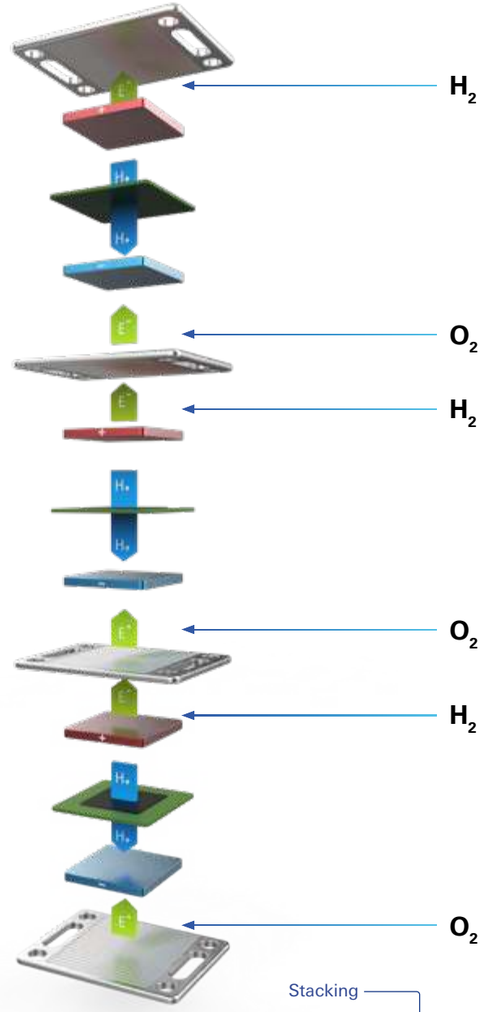
Testing

1 – 2 – 3 – 4 – 5 – 6 — 8 – 9 – 10 – 11 – 12 – 13 – 14 – 15

Stacking

By stacking fuel cells, manufacturers can achieve higher power outputs while maintaining the compact nature of these individual fuel cells. The stacking process demands precision to ensure efficient gas distribution, thermal management, and electrical connectivity.

The ASYS Group offers various solutions for stacking utilizing robotic systems and other handling technology.



Stacking

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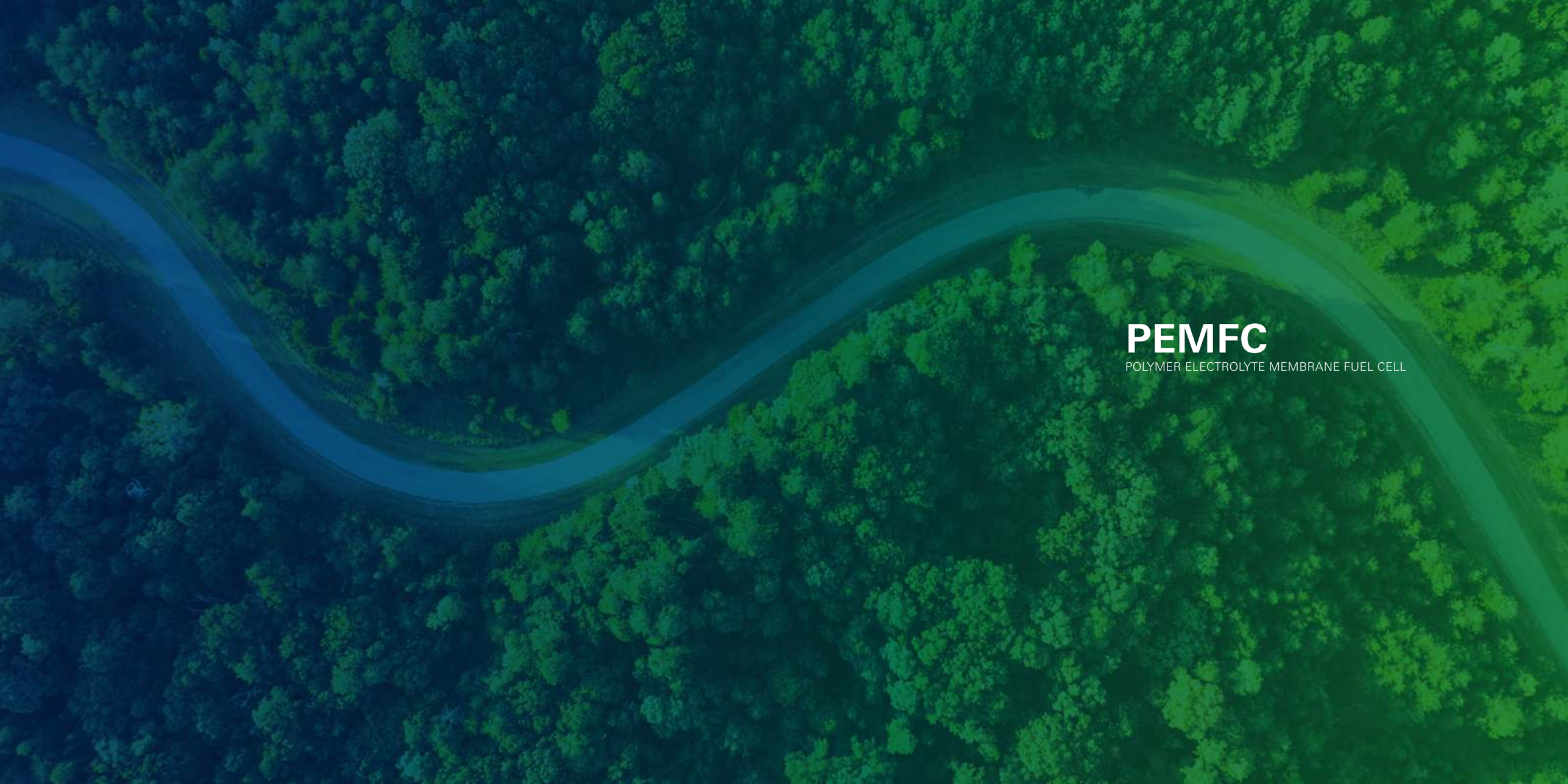


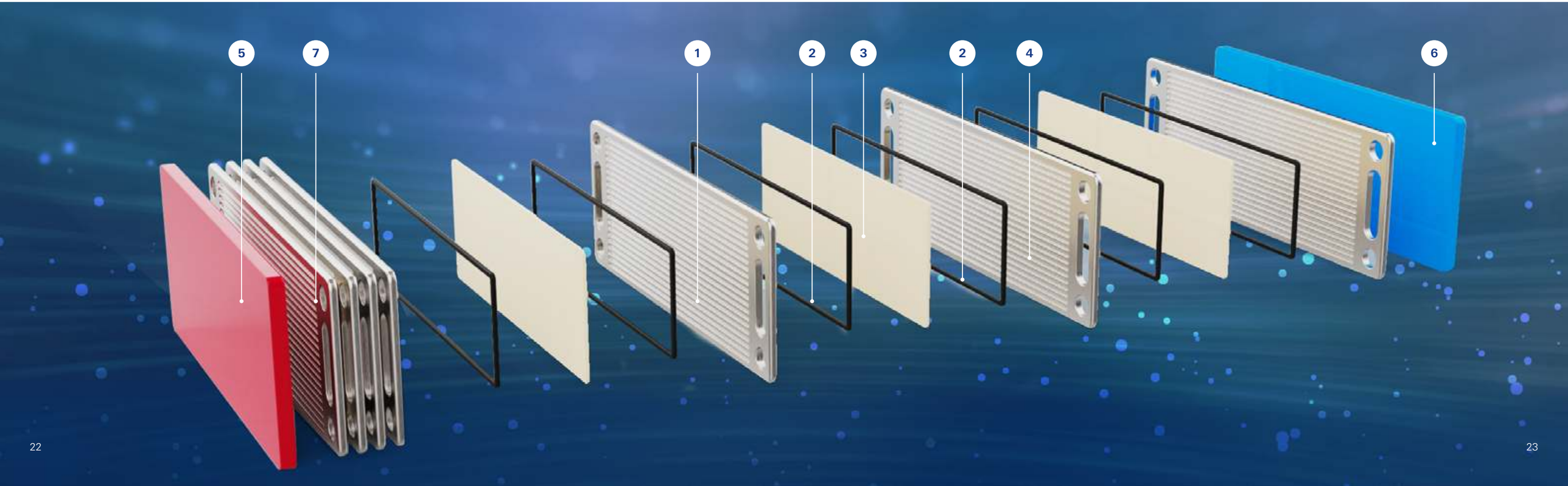
PEMFC

POLYMER ELECTROLYTE MEMBRANE FUEL CELL

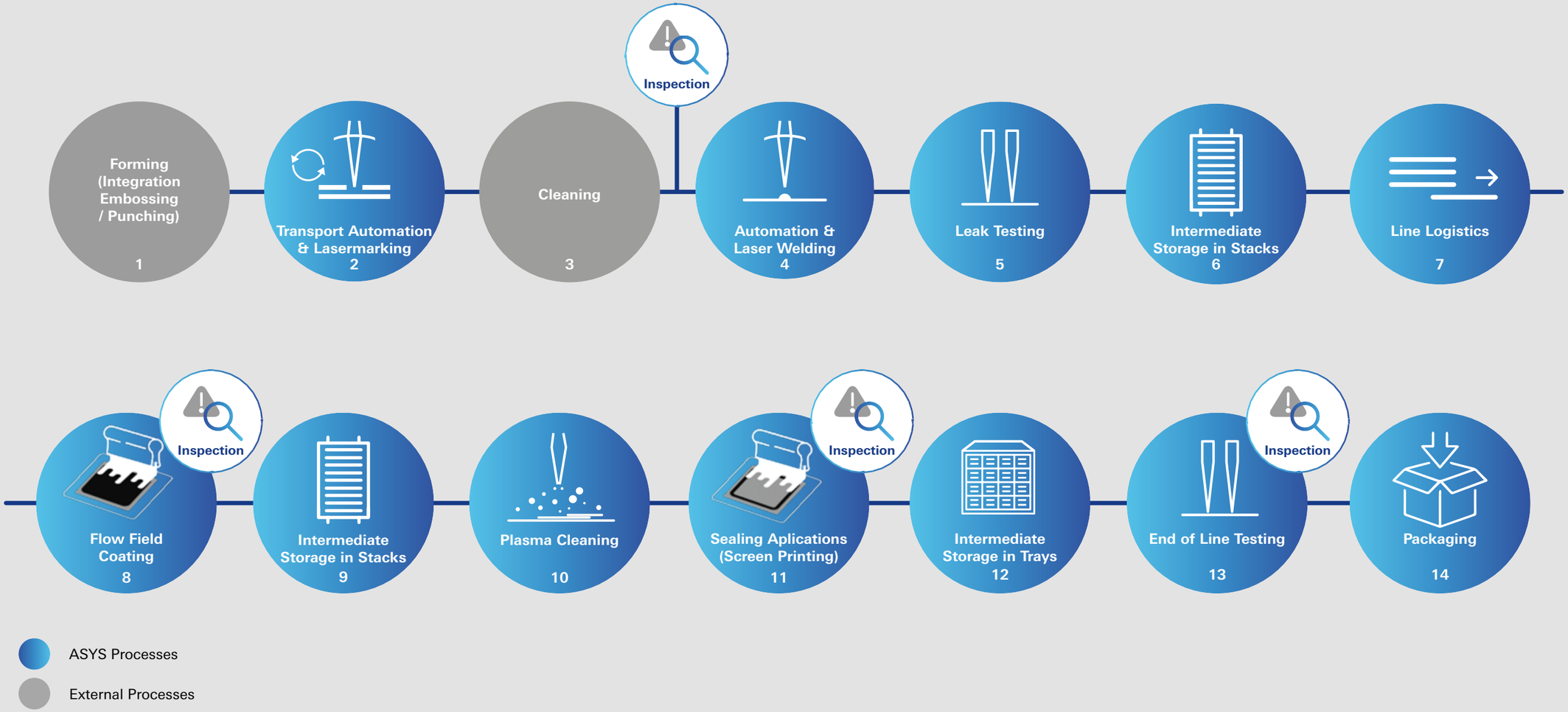
PEMFC Technology

As a low-temperature fuel cell, this cell is used in the majority of mobile applications. The main components of the PEMFC are the flexible membrane, the GDL (Gas Diffusion Layer), the assembled sealing structure (Sub Gasket), and the bipolar plate. In all listed elements, the ASYS Group offers solutions tailored to your needs.

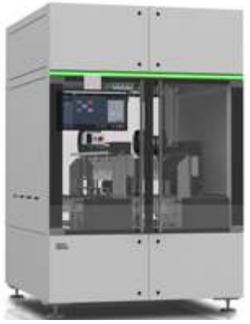
1. Bipolar Plate Anode
2. Silicone Gasket
3. MEA (Membrane Electrode Assembly)
4. Bipolar Plate Cathode
5. End Plate Anode
6. End Plate Cathode
7. 4-Cells Unit



Manufacturing of Bipolar Plate



Transport Automation & Laser Marking



To enable seamless traceability of the bipolar single plates, we offer our POLYPHOS MK laser marking with proven fiber laser technology. The single plates are automatically transported from the 1 Hz forming process and divided into four lanes. Two laser heads with state-of-the-art digital galvo scanners perform laser marking and code verification in a 4-second cycle time on two lanes each.

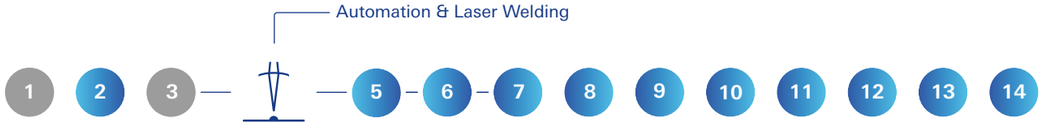
Automation & Laser Welding

Bipolar plates of PEMFCs play a critical role in ensuring the efficient operation, electrical connectivity, and longevity of a fuel cell stack by facilitating gas distribution, heat dissipation, and electron conduction between individual cells. Metallic bipolar plates consist of two thin stainless steel plates and have channels or flow fields that allow the reactant gases to flow over the electrode surfaces where electrochemical reactions take place. The electrochemical reaction within a fuel cell generates heat which is dissipated by a liquid coolant between two single plates. To prevent the mixing of reactant gases and the leakage of products, reactants, and coolant, proper sealing is crucial for the efficient operation of the fuel cell.

This sealing is performed by an inline remote welding process with a dual-head fixed galvo scanner duplet and 2 x 1 kW CW single-mode fiber laser on each of the multi stations.

Technical Information:

- Our POLYPHOS WL BPP high volume laser welding line is capable of welding bipolar plates up to 504 x 300 mm in size together in < 8 seconds total cycle time, achieving an annual capacity of 4 million BPP.
- Key facts achieved by our state-of-the-art laser echnology include a 35 µm spot size, < 100 µm seam width, and ± 50 µm accuracy.
- Quality is guaranteed by an integrated leak test.



Flow Field Coating

To improve the electrical contact to the MEA (Membrane Electrode Assembly), bipolar plates are usually coated. This is achieved by our innovative rotary coating system in which a defined film of material is continuously applied to the raised areas of the bipolar plate. The coated part is transferred directly through a high-speed drying system (IR based) and is inspected for defects or malfunctions. Our solution offers coating, drying and inspection in cycle times of below 4 seconds.

Screen Printing of the Sealing Structure

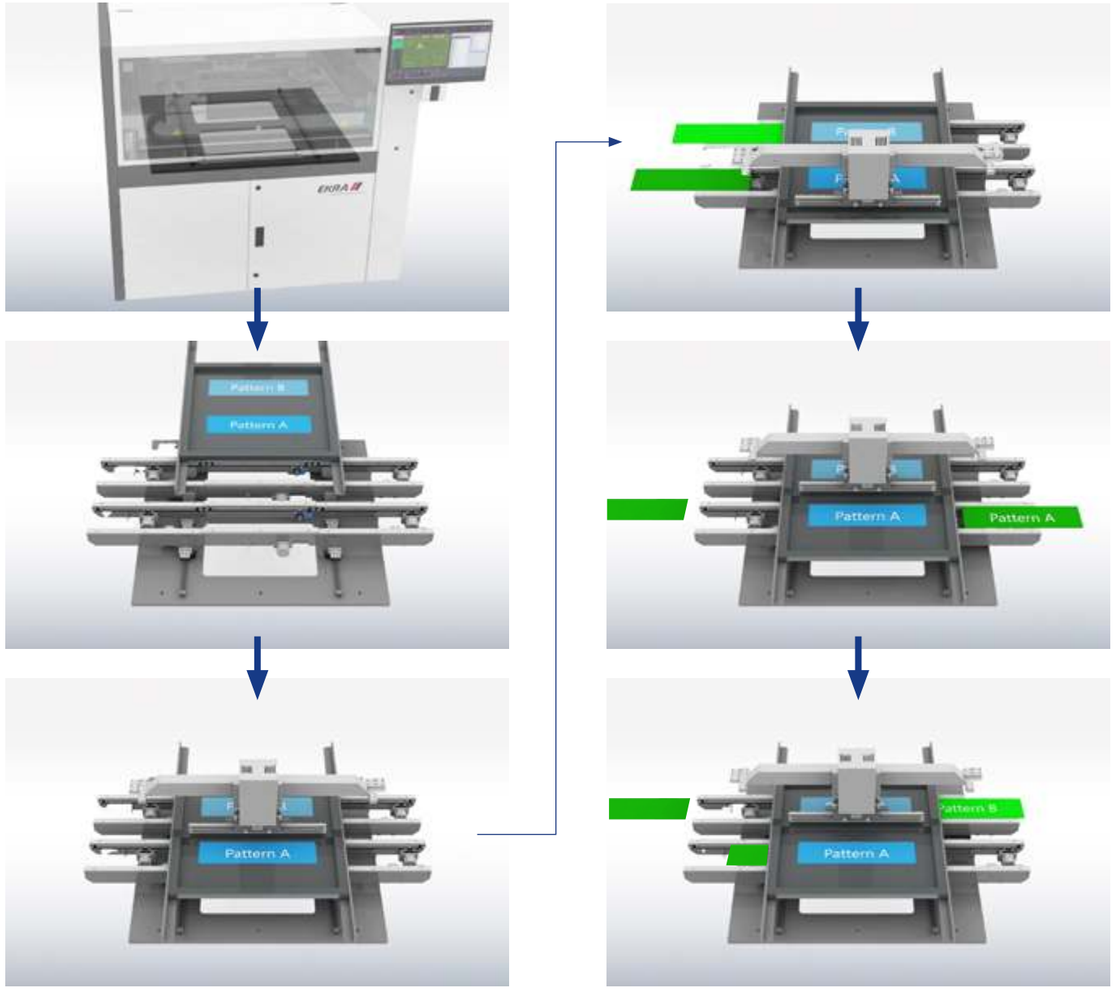
For the application of the sealing structure on the bipolar plate, we offer our patented industry leading XH4 printing system as part of a full sealing printing line. The bipolar plate is separated from stacks or magazines, cleaned and then fed to the screen-printing machine in multiple lanes.
The XH4 offers unique advantages which are setting new industry standards in high volume screen printing.

Technical Information:

- Enable efficient continuous printing with minimal transport times, thanks to an asynchronous multi-track transport system
- Create customized screen designs for substrates to maximize the benefits of screen printing
- The machine is equipped with a patented optical fiducial recognition system for high-quality results.

Please scan the QR code to check out the full video of the screen printing process.

XH4 Working Principle



End of Line Testing

Before the custom specific packaging step, final testing of bipolar plates is a critical step in ensuring their performance and durability. Our solutions for the end of line testing covers a leakage test to ensure that the bipolar plates are completely sealed to prevent the mixing of hydrogen and oxygen, which can lead to safety hazards. Leak testing involves pressurizing the welded bipolar plate with an under-pressure test or inert gas test, so it can detect any leaks in the bipolar plates or its seals. Beside the leak test an optical inspection process can be integrated to detect scratches or bending onto the surface of the bipolar plate and the edges of the cooling channels.

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Material Stocking / Logistics

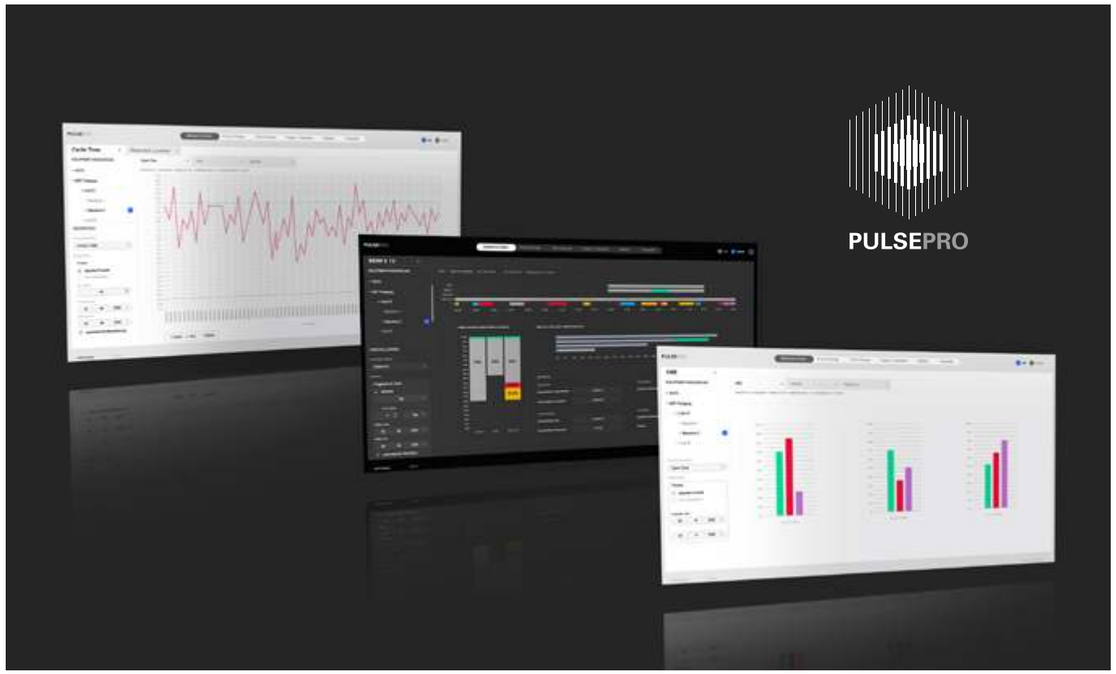
The large amount of material, e.g. bipolar plates, in the manufacturing environment, along with simultaneous different cycle times of involved processes, requires storage and buffering solutions for the bipolar plates.

Here, the ASYS Group offers storage systems like our Smart Buffer or Material Warehouse that can be directly installed in the production environment and operated with full automation for loading and unloading. In the fully automated production process, autonomous mobile robots (AMRs) handle the material transport of e.g. bipolar plates.

ASYS Smart Factory Manager

For the entire manufacturing environment, whether it is SOFC or PEMFC production, we provide an array of software modules under the name PULSE PRO. These modules encompass single-substrate tracking, pressure step control, operator support, and communication with existing MES systems. Additionally, the software interface can integrate third-party suppliers.

Feel free to reach out to us for tailored comprehensive solutions or innovative individual processes for your fuel cell production needs.



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ASYS GROUP

TRANSFORMING IDEAS
Automate, Digitalize & Connect

ELECTRONICS

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LIFE SCIENCE

ENERGY

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