WhitePaper

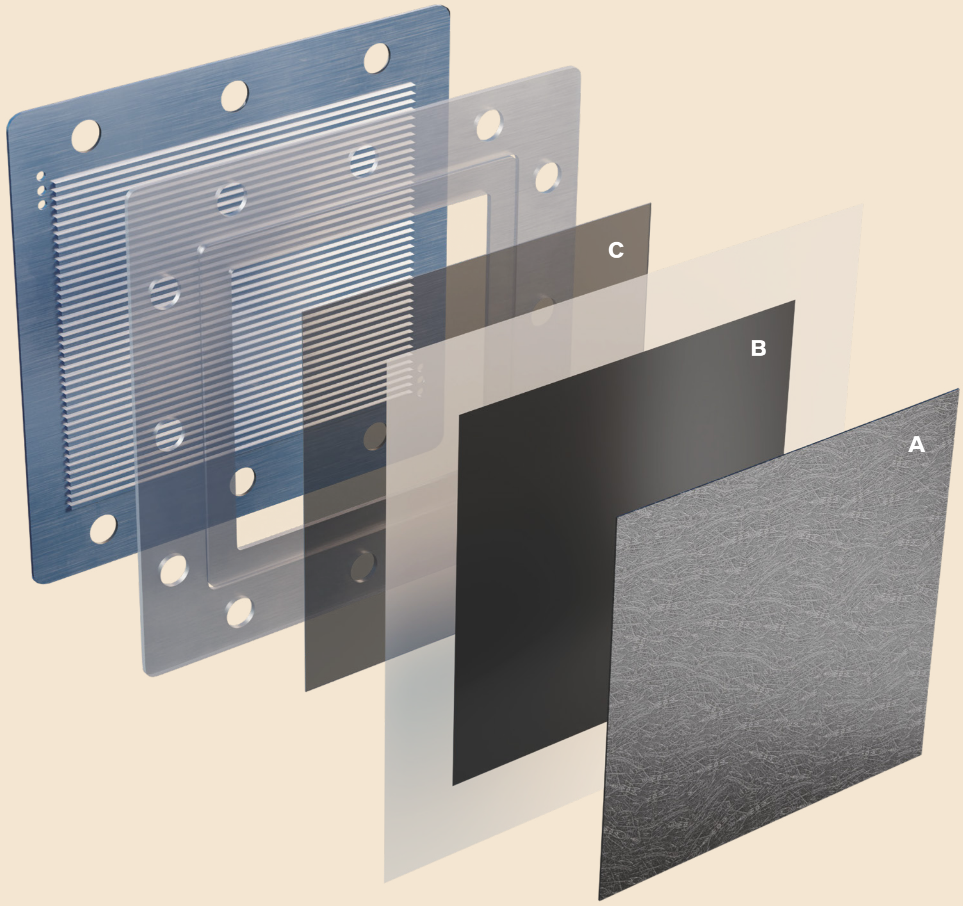
# Currento®

# Porous transport layer for water electrolysis

## The advantages of metal fiber media

Bekaert

# Contents




A. Porous transport layer B. Catalyst-coated membrane C. Carbon GDL

# Introduction

In high-performance electrolyzers, microns matter. As developers push for longer lifetimes, attention has shifted from visible components to those busy doing the heavy lifting – like Porous Transport Layers (PTLs). PTLs play a critical role in determining mass transport, electrical conductivity, and providing mechanical support to other critical components. And, in the race to produce efficient and durable green hydrogen at scale, the right PTL design can be a decisive advantage.

Among other materials, metal fiber-based PTLs are emerging as a front runner. Their tailored porosity, mechanical resilience, and proven stability under harsh operating conditions make these PTLs well-suited for the demands of modern electrolysis stacks. Let's explore how Bekaert's metal fiber PTLs are reshaping what's possible in the performance and reliability of electrolyzers.

# Porous Transport Layers (PTLs) in Electrolysis

To better understand the importance of a PTL, it's crucial to review the key components of electrochemical cells:

### 1. Cathode for Reduction Reaction

The site where the reduction reaction occurs, typically involving the gain of electrons.

### 2. Anode for Oxidation Reaction

The site where the oxidation reaction occurs, typically involving the loss of electrons.

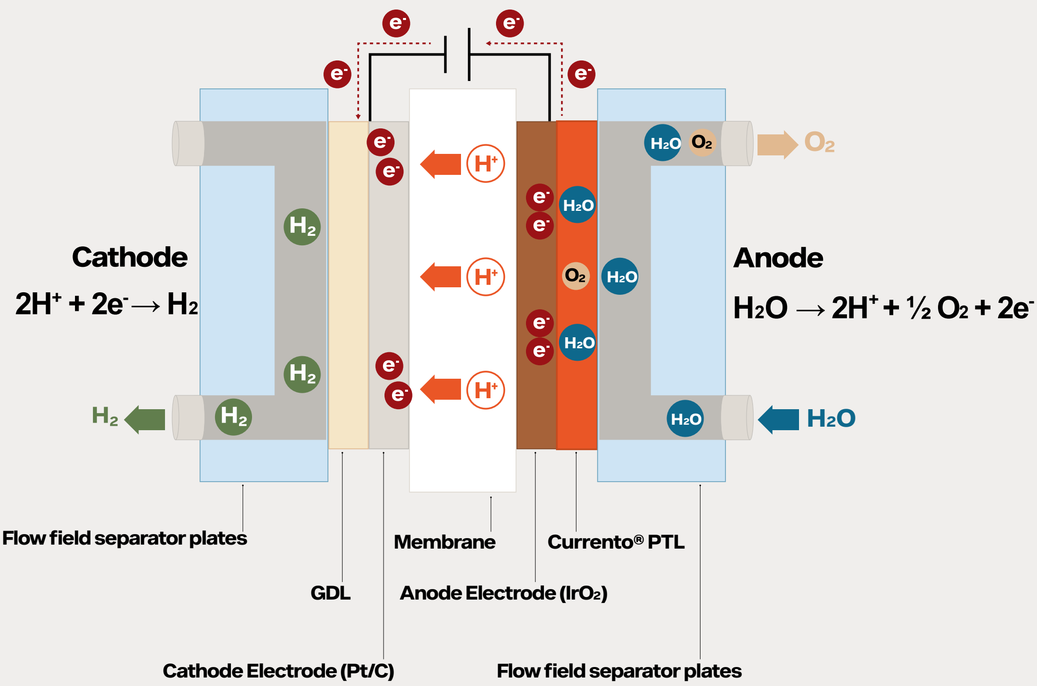
### 3. PTL Part for PEM/AEM Electrolyzer Anodes

The PTL usually serves as a substrate for the anode catalyst layer, and in seldom cases is used on the cathode as a substrate, facilitating the overall electrolysis process.

In proton exchange membrane (PEM) and anion exchange membrane (AEM) electrolyzers, the PTL is more than just an interlayer. It's a critical performance enabler. Positioned between the catalyst layer and the bipolar plate, the PTL manages a complex task:

- Ensuring uniform reactant distribution and product gas removal
- Maintaining efficient electron and heat flow
- Providing strong mechanical support
- Withstanding harsh and corrosive environments (over tens of thousands of operating hours)

## PEM Electrolysis

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# Core Functions of a PTL

A high-performing PTL must meet multiple, sometimes competing, requirements to support efficient electrolysis and stack longevity:

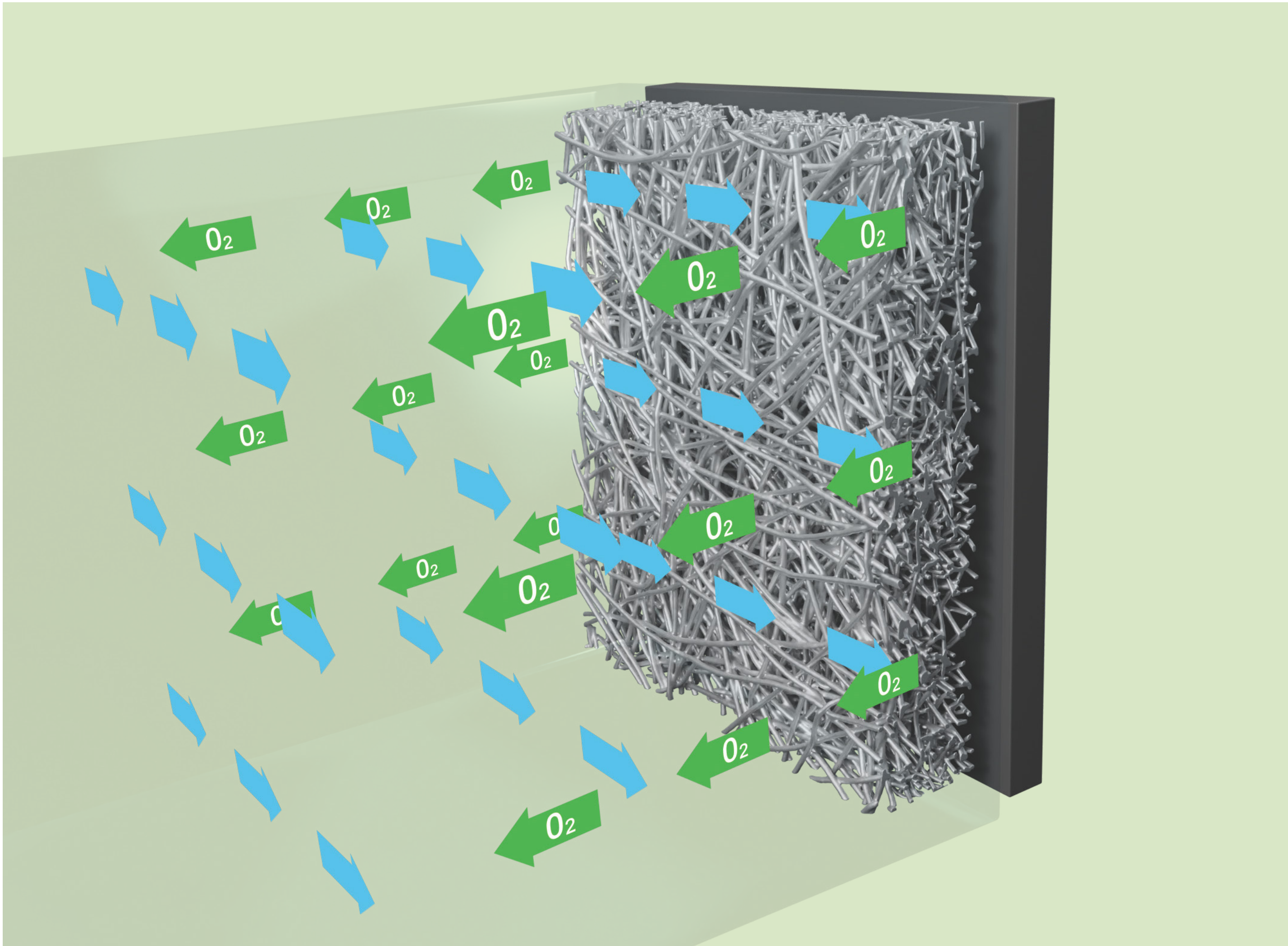
### 1. Mass Transport
PTLs must deliver reactant water to the catalyst layer while allowing product gases (primarily oxygen at the anode) to exit without blockage or buildup.

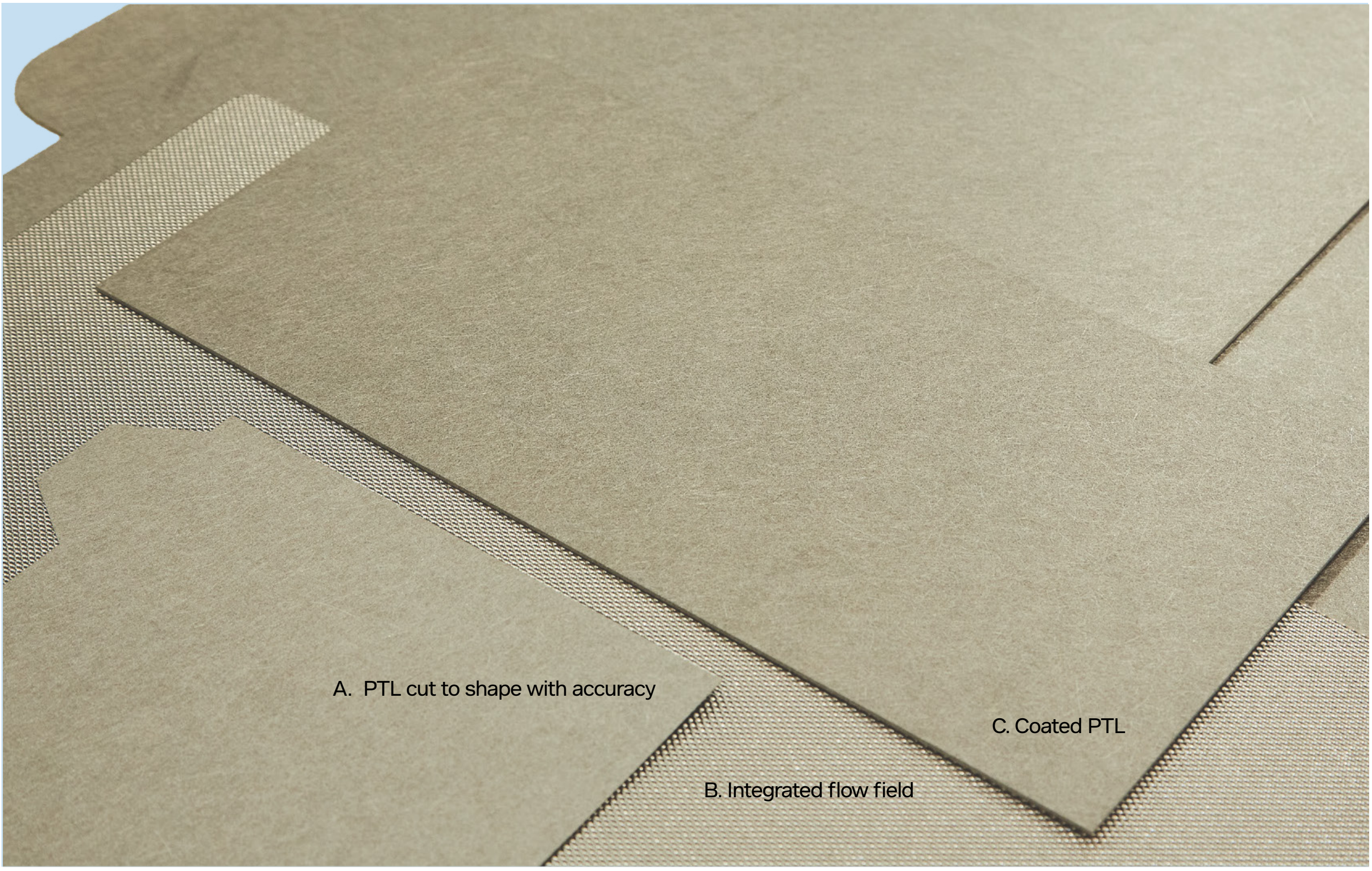
### 2. Electrical Conductivity
Provides a continuous path for electrons to flow from the catalyst layer to the bipolar plate, minimizing resistance losses.

### 3. Thermal Conductivity
Heat generated during electrochemical reactions must be dissipated evenly to prevent local hotspots while maintaining stable operating conditions.

### 4. Mechanical Stability
The PTL supports the catalyst layer and membrane, helping to preserve stack compression and protect against physical degradation.

### 5. Corrosion Resistance
Operating at high voltages in acidic or alkaline environments demands materials that can maintain structural integrity over tens of thousands of hours.






# Material Selection for PTLs in Electrolysis Systems

Selecting the right PTL material is not a one-size-fits-all decision. It requires a careful understanding of the electrochemical environment, especially on the anode side. On the anode side, PTLs undergo aggressive conditions which can rapidly degrade unsuitable materials. And because it directly influences conductivity, corrosion resistance, mechanical integrity, and cost, material selection ultimately affects the performance and lifespan of your electrolyzer stack.

**Titanium (Ti)** is the benchmark material for PTLs in PEM electrolyzers. The anode environment of PEM systems is both strongly acidic and highly oxidative, posing a unique challenge to materials exposed to these conditions. Titanium offers corrosion resistance and mechanical stability even under long-duration stress. However, titanium is also expensive and difficult to process, which increases system cost overall.

**Nickel (Ni)** is the most commonly used material for PTLs in AEM electrolyzers. Its stability and conductivity enable nickel to outperform other materials under the alkaline conditions of AEM. Plus, for lower-cost systems or mid-scale deployment, nickel offers a suitable option in terms of affordability and ease of fabrication (especially compared to titanium), therefore making AEM electrolyzers more attractive to certain degrees.

**Stainless steel (SS)** offers a compelling balance between cost and performance in select AEM applications. While not typically used in PEM systems due to poor acid resistance, stainless steel can be suitable in AEM stacks where the pH is less extreme. This material's widespread availability and ease of fabrication also make it an excellent candidate for cost-sensitive systems. But, in terms of length of durability, stainless steel must be validated on a case-by-case basis.

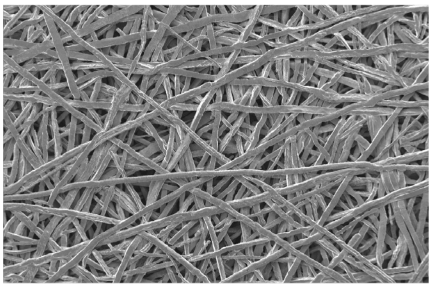
# Advantages of Metal Fiber PTLs (Compared to Other Types of PTLs)

**Metal fibers offer several advantages over other types of PTLs.** For example, metal fiber PTLs exhibit elastic deformation that provides flexibility, medium to high porosity for efficient mass transport at high current densities, and good mechanical and electrical properties. **In PEM**, highly corrosive acidic anode conditions require titanium (often Pt-coated) for long-term durability.

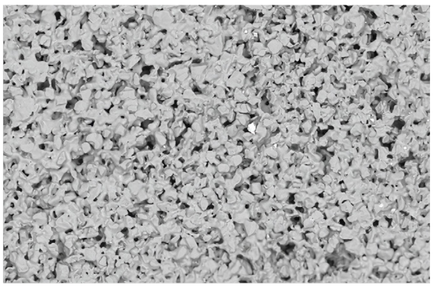
**In AEM**, the alkaline environment enables the use of nickel or stainless steel PTLs to balance cost and stability. These distinctions in material and environment highlight how fiber-based PTLs perform against mesh, powder, or foam alternatives, as shown below.

### Table 1 - Fiber PTL vs. Powder and Mesh PTLs (PEM)

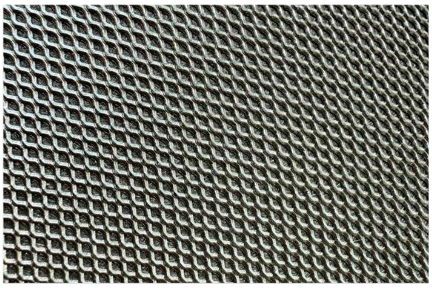
| | Fiber | Powder | Mesh | Performance benefits |
|---|---|---|---|---|
| **Mechanical compliance under pressure (springback)** | **Elastic deformation** | Less elastic deformation | Plastic deformation | Sustained pressure on CCM after pressure cycling |
| **Porosity** | **Medium to high** | Low to Medium | High | Oustanding mass transport at high current densities |
| **Flexibility** | **High** | Low | Low | Automated assembly Large dimensions, continuous roll |
| **Integration with other stack components** | **High** | Lower | Medium | Reduced complexity for stack assembly; Mesh not optimized for PEM flow fields (lack of 2-phase flow understanding) |



Fiber



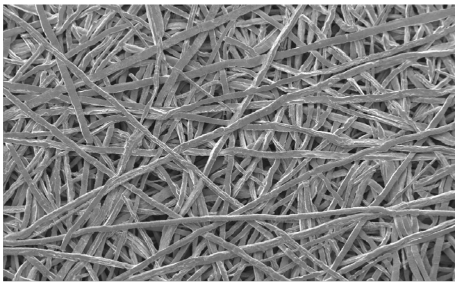
Powder



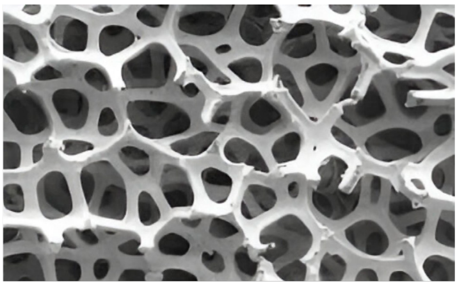
Mesh

## Table 2 - Fiber PTL vs. Foam PTL (AEM)

| | Fiber | Foam | Performance benefits |
|---|---|---|---|
| **Interface with membrane** | Smooth | Sharp edges | Longer membrane lifetime<br>Avoids micro-punctures |
| **Roughness of surface** | Smooth | Rough | Higher current density<br>Avoids micro-punctures |
| **Contact surface area to membrane** | Higher | Lower | Lower contact resistance<br>Tunable for optimal coatability |
| **Active catalytic surface area ($m^2/m^3$)** | Higher | Lower | Higher catalytic activity |
| **Minimal thickness** | > 100 µm | > 300 µm | Lower contact resistance<br>Tunable for optimal coatability |
| **Mechanical compliance under pressure (springback effect)** | Elastic deformation | Rigid, plastic deformation | Sustained pressure on membrane after pressure cycling |
| **Flexibility** | High | Lower | Automated assembly Large dimensions, continuous roll |



Fiber

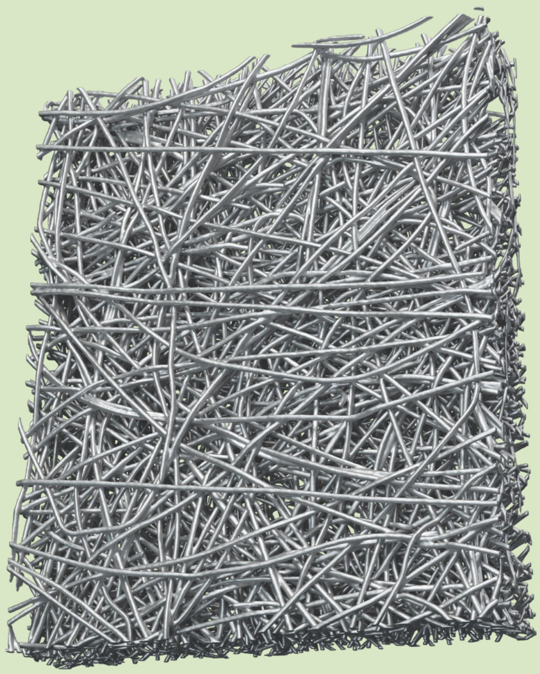


Foam

# Next-Gen PTLs: Engineering Efficiency and Durability

As electrolyzer technologies advance to meet the demands of scale, efficiency, and cost reduction, **PTLs must continue to evolve**. Traditional PTL materials and designs, albeit foundational, are beginning to show limitations when advancements are required in industrial-scale hydrogen production for improved efficiency and lowered cost. In response, researchers and manufacturers are exploring **new PTL architectures, materials, and fabrication techniques**, all for the sake of achieving higher performance in more extreme conditions without compromising durability or manufacturability

One key direction is found in the development of **engineered interface and porosity**, enabling precise control over the catalyst interface, fluid dynamics, and mass transfer. By moving beyond current PTLs to designed interface and porosity, PTLs **can achieve optimized interactions with the catalyst layer and thin membrane, while maintaining efficient mass transport**, both of which are critical for high-efficiency operation with thinner membranes and lower catalyst loading to be used in electrolyzers in the future.



# Summary

**Why fiber PTLs?**
Metal fiber porous transport layers **deliver significant performance advantages** for modern electrolyzers. They combine high electrical conductivity with mechanical resilience to withstand pressure, cycling, and harsh conditions.

Plus, using corrosion-resistant metals, alloys, and coatings, metal fiber PTLs maintain integrity over long operation. Making it a reliable choice when efficiency, longevity, and robustness matter most.

**Future technologies**
Metal fiber PTLs are improving fast. The very next wave of technology is centered on refining structure and materials to push even better performance and durability. Key areas under development include:

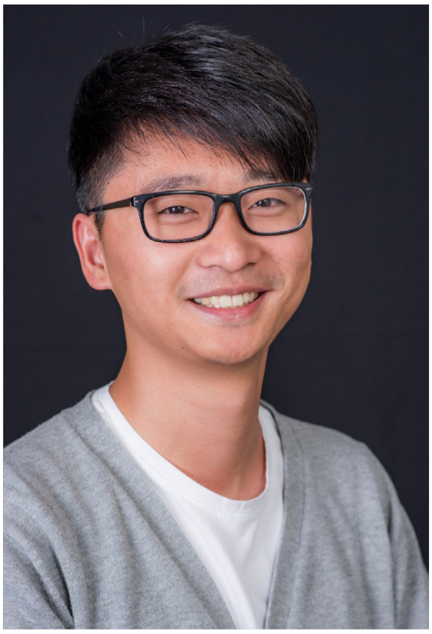
- **Smoother surfaces**
  Smooth surface (lower surface roughness) improves durability and lowers contact resistance, especially for MEAs with thinner membranes and lower catalyst loadings.

- **Optimized pore quality and integrity**
  Tailored pore sizes can lead to more efficient mass transport, and therefore less energy loss.

- **Thinner, more effective coatings**
  Coatings protect PTLs, but added thickness increases cost. New developments minimize thickness while ensuring uniform coverage and protection.

We're advancing the next generation of PTL technology, **backed by over 20 years of experience**. Refined surfaces, precisely sized pores, ultra-thin protective layers, and more. To not only provide more value but also extend the life of hydrogen systems and beyond.

# Contributor



**Dr. Sichao Ma**

Dr. Sichao Ma, Global Technical Application Lead, supplies a wealth of experience and insight to the hydrogen segment at Bekaert. With over 14 years spent in the clean energy sector, Dr. Ma has developed deep expertise in catalysts, electrodes, and system integration for both water and $CO_2$ electrolysis. His background spans electrolyzer development and advanced materials – key areas driving innovation in green hydrogen technologies.

Dr. Ma holds a Ph.D. in Materials Chemistry from the University of Illinois at Urbana-Champaign and has contributed significantly to the field. He has 28 peer-reviewed publications and has been granted 7 patents. His insights are backed by a strong foundation in applied research and a proven ability to translate science into scalable solutions.

bekaert.com/currento

NV Bekaert SA
Bekaertstraat 2
BE-8550 Zwevegem
T +32 56 76 61 11
bft@bekaert.com