

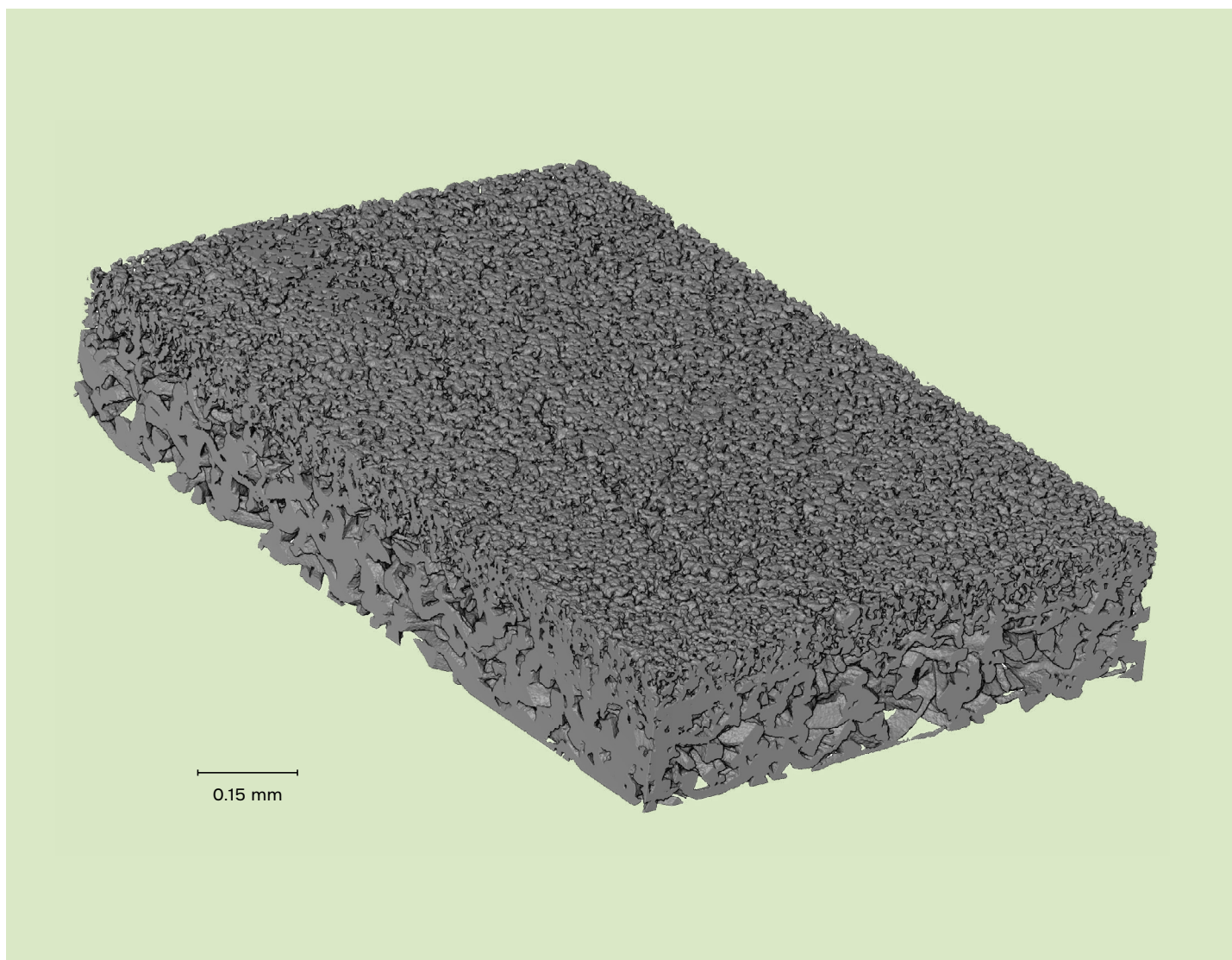
Inside the Bekaert MPL

Engineered
microstructures
for next-generation
PEM performance



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From function to design

The porous transport layer (PTL) is the multifunctional bridge of a Proton Exchange Membrane Water Electrolyzer (PEMWE), positioned between the bipolar plate and the catalyst coated membrane (CCM). Its design must satisfy four critical functions: providing mechanical support for the CCM, ensuring efficient electrical and thermal conduction, supplying reactant water to the catalyst layer, and facilitating the rapid removal of produced oxygen gas. Traditional single-layer PTLs often struggle to balance these competing requirements.

Bekaert's first white paper, "Not just a layer," established why the microporous layer (MPL) has become a decisive component in PEMWE. Our new MPL product integrates a fine powder layer onto

a titanium fiber substrate to specifically address the interfacial contact area and mass transport challenges of next generation CCMs, as membranes get thinner and iridium loadings fall. In short, the MPL is no longer an optional finish - it is a functional interface that the whole cell depends on.

This paper opens that system up: its composition, its microstructure, the design levers it unlocks, how it integrates with the PTL, and the first evidence that design choices translate into measurable performance.

Composition of the Bekaert MPL

The Bekaert MPL leverages a dual-architecture design, with a defined set of 2 building blocks:

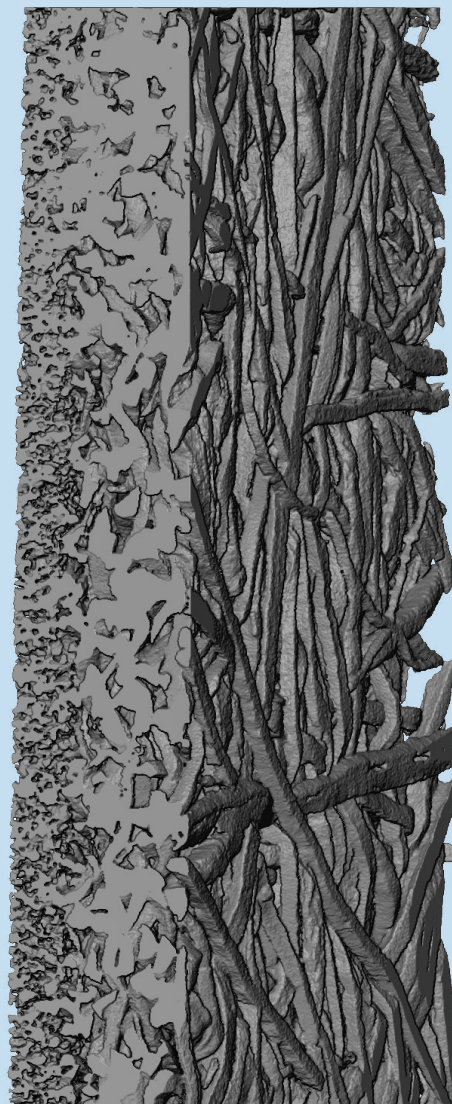
Two building blocks, two jobs

Metal fiber network (Ti-based)

The advanced fiber layer combines mechanical adaptability with outstanding transport performance in a high efficiency structure. Its elastic compression behavior reliably compensates for thickness variations - even in adjacent cell components - ensuring consistent contact quality. At the same time, its high porosity provides excellent permeability, enabling effective flow even at low pressure drops. This results in exceptional mass transport capabilities for both liquids and gases. Complementing these properties, diffusion-bonded connections form a corrosion-resistant, electrically conductive network, significantly enhancing long-term stability and overall system performance.

Powder phase

The powder-based MPL is specifically engineered to form an optimized interphase with the catalyst layer, delivering high electrical conductivity while effectively mitigating increased resistance associated with reduced IrOx loadings. This enables more efficient utilization of active catalyst sites and supports overall performance optimization. In addition, the MPL provides mechanical stabilization of the membrane under elevated differential pressures and dynamic operating conditions. Both functions rely on maximizing contact areas while maintaining minimal distances between contact points, ensuring uniform load distribution, robust interfacial connectivity, and reliable long-term operation. While the fine pore structure at low porosity may potentially limit mass transport, the powder layer thickness is intentionally minimized to mitigate this effect and preserve efficient transport of reactants and products.



0.2 mm

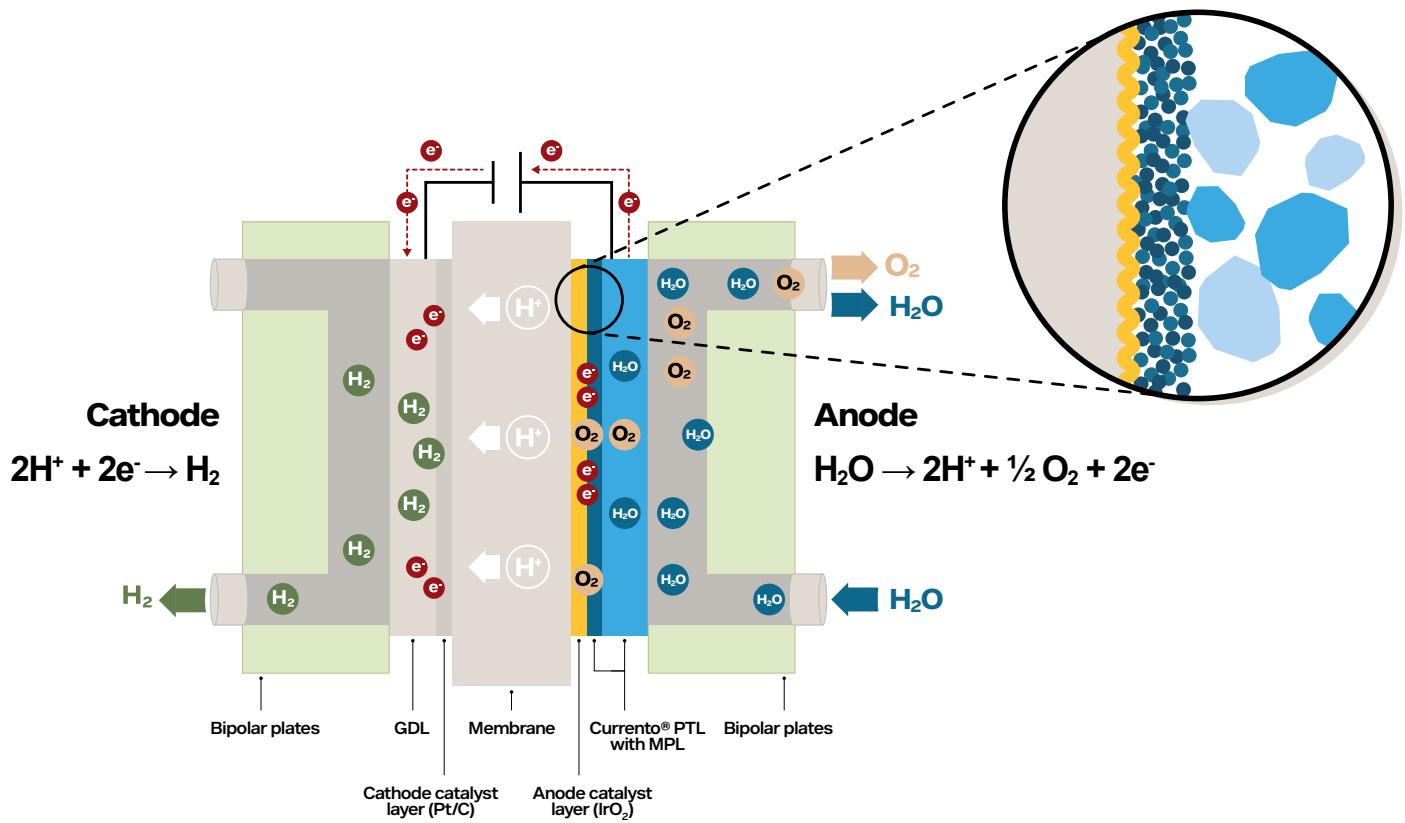


Figure 1: The Bekaert MPL as an engineered layer on the PTL – a titanium fiber network combined with a controlled powder phase, between the PTL and the low-iridium catalyst layer.

The value of combining the two phases is **functional decoupling**. In a single-material layer, the properties that govern mechanics, conductivity and pore structure are coupled - improving one tends to compromise another. The hybrid architecture separates these roles: the fiber network is optimized for load bearing and conductivity, while the powder phase is optimized independently for interfacial contact and pore tuning. Each function can be advanced without paying a penalty on the others.

Advantages of the microstructure & architecture fiber substrate versus powder substrate

What the microstructure decides

Contact uniformity

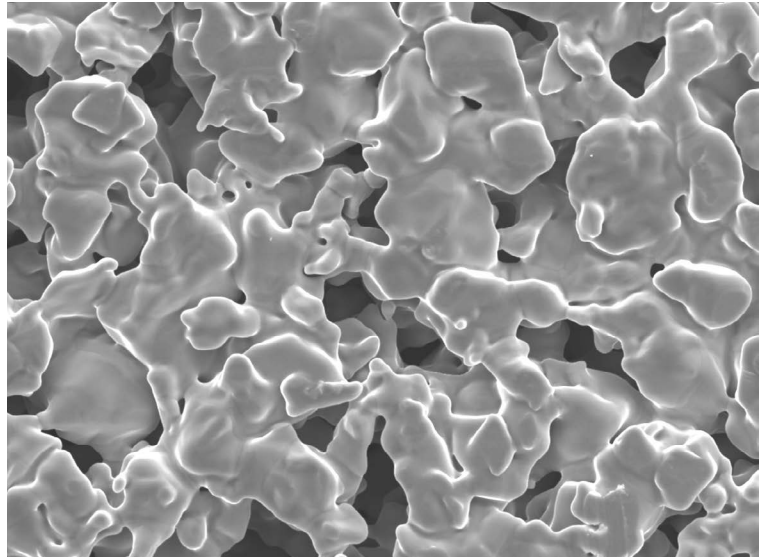
A lower-roughness gives more uniform contact surface on layers and reduces local hot spots and uneven current distribution, which matters most under thin membranes. Fiber layer may improve it due to its elastic deformation properties.

Permeability versus resistance

The connected fiber network keeps through-plane permeability high for water and gas. More compact microporous powder layers generate the contact area need to get lower interfacial resistance.

Bubble detachment paths

Engineered, preferential channels let oxygen bubbles nucleate, grow and detach quickly, keeping catalyst sites clear at high current density.



Side view (y-direction)

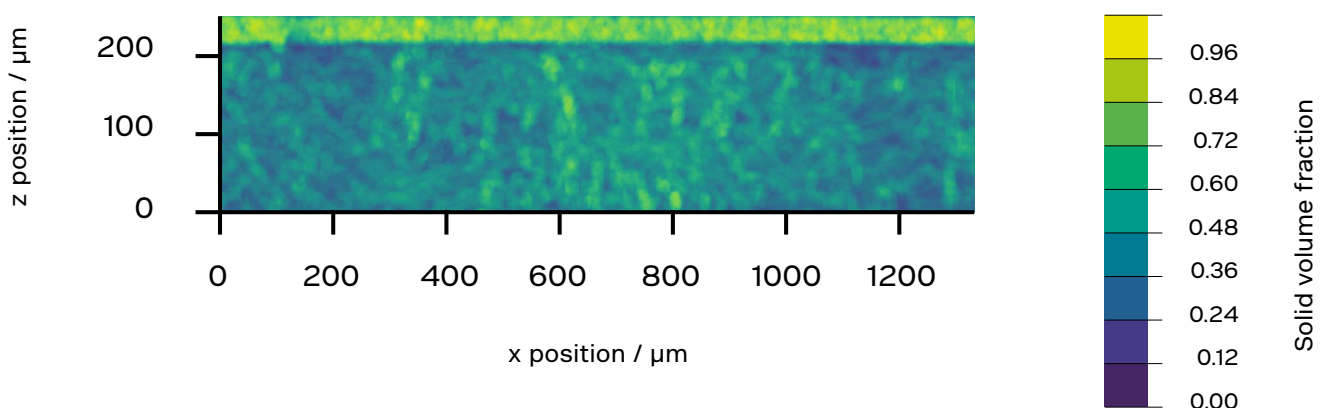


Figure 2: Powder-based versus fiber-and-powder microstructure. The fiber network creates an open, connected pore system with engineered pathways for water supply and oxygen removal.

Tunability: the design space of the Currento[®] MPL

Bekaert MPL is engineered within its framework of key structural parameters that are adjustable. This is the practical advantage of the fiber-and-powder

platform: it opens a design space rather than fixing a single recipe.

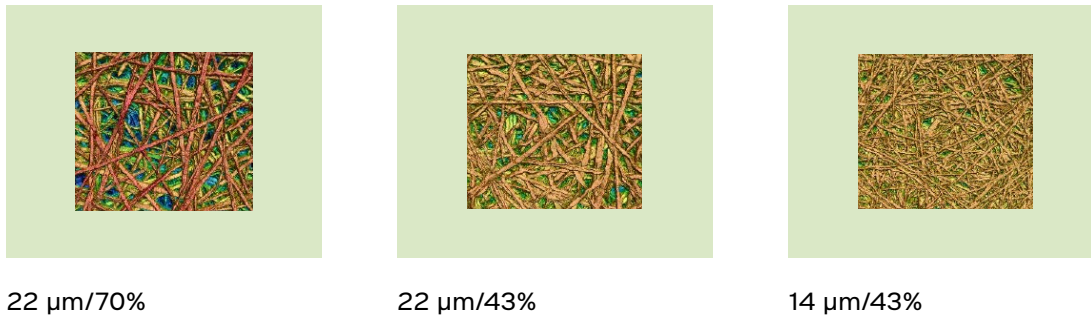
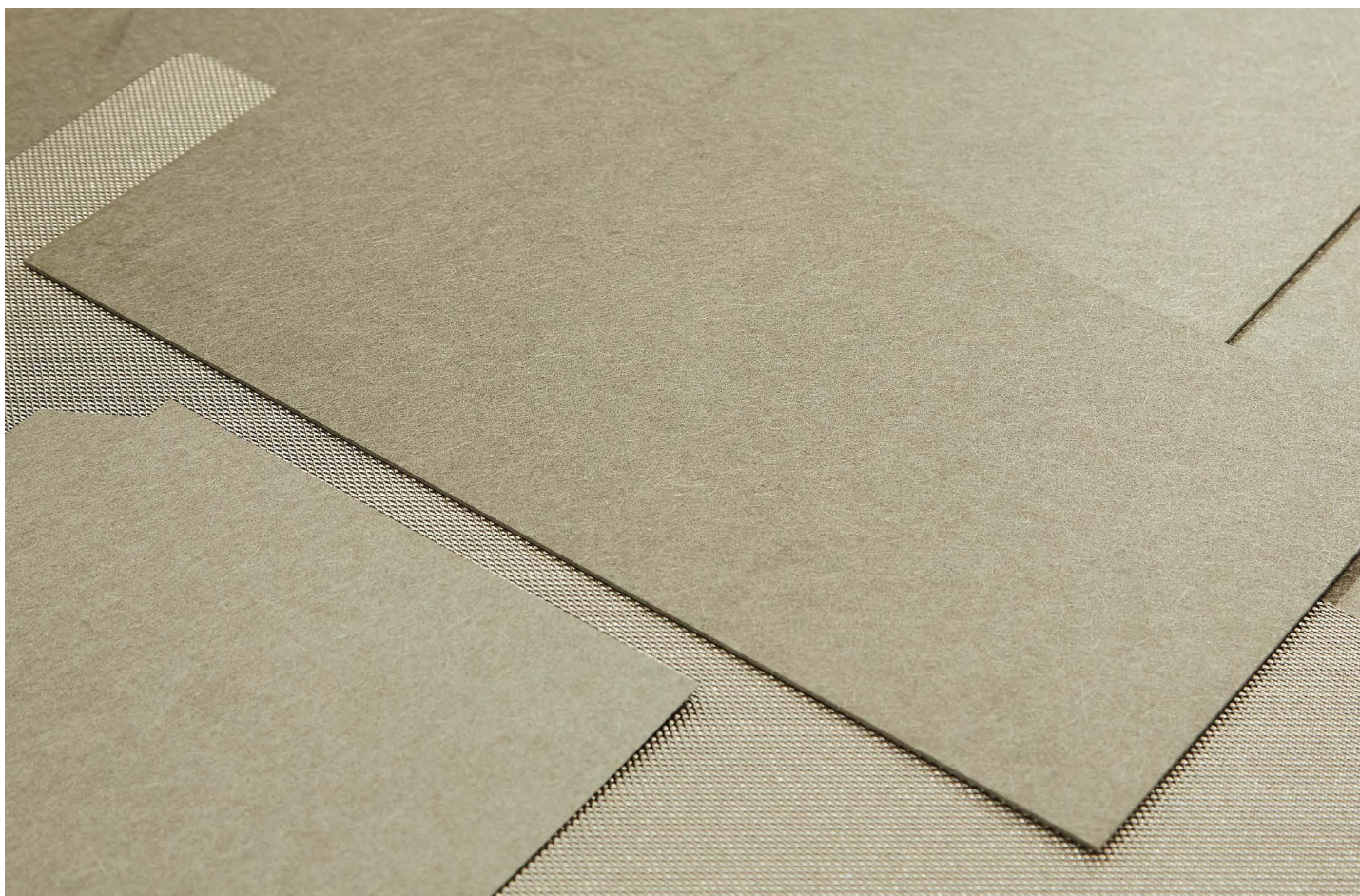


Figure 3: Design levers of the fiber-based MPL and the application outcomes they unlock – enabling application-specific engineering rather than a single fixed product.

Adjustable parameters

- **Fiber diameter:** setting conductivity, mechanical support and the coarse pore scale.
- **Layer thickness:** essential for optimal permeability modulating MPL thickness.
- **Porosity gradient:** grading pore size from the PTL toward the CL to balance water supply and gas evacuation.

Tuning these levers lets the same platform adapt to different stack designs: to a given **membrane thickness**, to a target **iridium loading**, and to the specific architecture of an individual OEM's cell. The result is a move away from a one-size-fits-all component toward MPL parameters customized for customer needs based on adjustable variable already mentioned to find the optimal mix of parameters.



Beyond a standalone layer

The true strength of this product lies in its graded porous structure. Rather than being a standalone component, the MPL is integrated as a top layer of a pore-graded assembly. This design creates a porosity gradient that increases from the CCM interface toward the flow-field. This gradient exploits the natural tendency of oxygen bubbles to migrate toward regions with larger pores and higher porosity, effectively “pumping” gas away from the reaction sites while keeping the interface saturated with reactant water.

Designing the layers together reduces interfacial mismatch and the resistance and stress concentrations that come with it, improves mechanical robustness under compression and pressure cycling, and simplifies stack integration - fewer interfaces and fewer separately qualified parts. Delivered through Bekaert’s integrated PTL, MPL, coating and cutting offering, the customer receives an OEM-ready component to final specification from a single supplier.

What this enables for PEM electrolyzers

Read against the technology trends set out in WP1 - thinner membranes, lower precious-metal loadings and higher current densities - the Bekaert MPL is aligned with where next-generation stacks are heading:

- **Low iridium loadings**

As iridium loading is reduced (~0.2–0.6 mg/cm² range), catalyst layers become thin and discontinuous. Our MPL provides the in-plane electronic conductivity needed to incorporate these isolated catalyst sections, raising overall the catalyst utilization.

- **Thin membranes**

Next-gen thin membranes (~20–80 µm range) reduce ohmic losses but are mechanically fragile. The smooth contact surface of our MPL provides a safe contact interface and a uniform mechanical support, reducing significantly the risk of membrane deformation and delamination, pinholes and local dry-out.

- **High current densities**

By mitigating oxygen accumulation at the interface, our graded design allows PEMWE to operate at much higher current densities with lower mass transport overpotential. Together these enable more aggressive, compact stack designs - smaller active area and reduced iridium content for the same output - which is precisely the lever the industry needs to bring down the levelized cost of hydrogen (LCOH), supported by Bekaert's industrial-scale, batch-consistent manufacturing.





From architecture to performance

This paper has shown how MPL design - composition, microstructure, tunability and integration with the PTL - shapes what the layer can do inside a PEM electrolyzer. Where WP1 explained why the MPL matters, WP2 has shown how the Bekaert MPL is built to deliver, and the first beginning-of-life results indicate the design intent carries through to the cell.

The next step is proof at depth. The third paper in this series moves from architecture to evidence - demonstrating, through measured IV and impedance data, durability and hydrogen-crossover testing, how this engineered design translates into measurable, repeatable superiority over conventional MPL solutions.

Contributors

Dieter Hellert

Dieter Hellert graduated from Julius-Maximilians-University in Würzburg in 1995 with a PhD in natural sciences with a thesis in metalorganic chemistry. Four years later, he joined Bekaert developing customized products to transfer application requirements into real life solutions. With over 25 years of experience in various functions, Dieter has held the role of market manager, business development manager, and product manager within hydrogen at Bekaert. He brings deep expertise in advanced metal fiber compositions for filtration, wicking, and conductive plastics, successfully translating electrolyzer stack requirements into PTL solutions validated by leading PEM electrolyzer OEMs. In his role as product manager, Dieter has driven the development of advanced MPL structures for more than 5 years. He initiated and supported the track from supply of semi-finished goods to PTLs, ready for stack assembly comprising cut to final dimensions and protective coating features.



Thomas Favet

Thomas Favet is Lead R&D Ti PTL at Bekaert, where he focuses on the development of titanium porous transport layer technologies for hydrogen applications. He holds a PhD in Chemistry and Materials/Photo electrochemistry from the University of Strasbourg (FR) and the INRS (Ca), with research focused on photoelectrochemical hydrogen production. His background combines materials science, electrochemistry and hydrogen technology. At Bekaert, he has also authored technical content on metal-fiber PTLs and their role in improving the performance of PEM electrolyzers.

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