
SMOLTEK
Development Partner for Next
Generation PEM Electrolyzers

SMOLTEK

NANOTECH FOR COST LEADERSHIP

Minimize iridium loading with nanotechnology

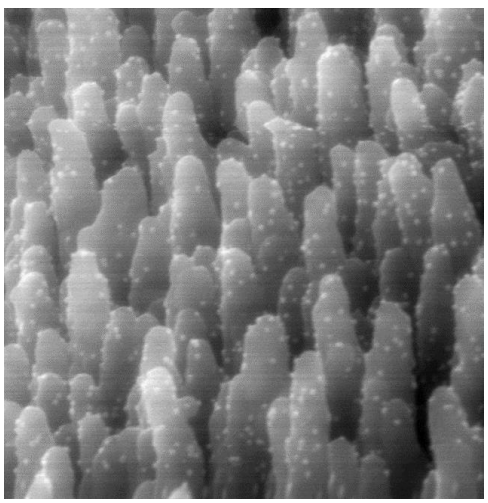
With an ultra-thin layer of iridium distributed on a mega-sized surface, Smoltek has the solution for the future cost leaders in PEM electrolyzers

Beat competition. Become thousands of euros cheaper per square meter PEMWE cell

Smoltek Hydrogen's disruptive nanotechnology enables extensive cost savings for PEM electrolyzers

While the green hydrogen market is booming, dramatic iridium price increase from today's 150 to 700 €/g in 2030 is predicted

With a minimum use of iridium, the coating only cost 20% of competing solutions.



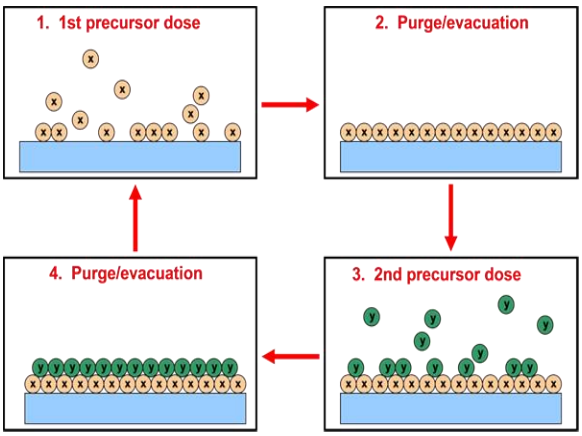
Nanotechnology to get larger surface and thinner layers

Nanofibers on PTL expands the surface area up to 30X

Since the full area is covered with iridium catalyst, electrolysis takes place everywhere of the large surface.

To place iridium on the fibers several nanotechnology methods can be used, working molecule by molecule. The Iridium layer therefore is extremely thin.

Nanotechnologies



ALD principle - two precursors are used, creating perfect layers of molecules without any voids or cracks.

PECVD Plasma enhanced chemical vapor deposition
ALD Atomic layer deposition
Sputter Physical deposition of ejected atoms
Electro deposition Electro-chemical deposition

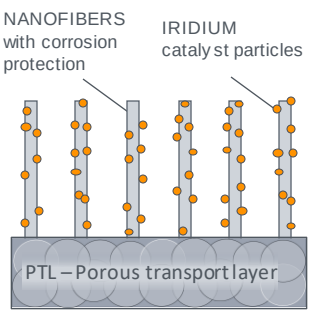
SMOLTEK ECM
Anode Porous Transport Electrode
PEM Electrolyzer Cell Material with 0.1 mg Ir/cm^2

SMOLTEK HYDROGEN

Development partner for next generation electrolyzers

Pushing the limits of what is possible

Smoltek Hydrogen's disruptive nanotechnology reduces iridium loading in PEM electrolyzers down to 0.1 mg/cm^2 .



All nanofibers are electrically conductive and covered with corrosion protection and iridium catalyst

Choose your iridium concept now

The price of iridium is around 150,000 €/kg already today and is predicted to be at least 4 times higher in 2030.

To stay competitive, electrolyzer manufacturers are now choosing their future iridium catalyst concept

Roadmap – Developing with Smoltek

2023	Lab samples 22x22 and 50x50 mm^2
2024	Lab samples – A4 size Lab-sized industrial samples
2025	Test-series of A4 industrial samples
2026	Small-scale industrial production
2027	Ramping up high-volume production

20 years in nanotechnology

Smoltek Hydrogen is part of the Smoltek Group - a listed nanotechnology company founded in 2005 in Gothenburg. Smoltek Hydrogen is the business area developing advanced material solutions for the green hydrogen applications.

With nanoscale technologies from the semiconductor industry, we build with atoms and molecules.

Full-cell PEM electrolyzer tests in H2LAB

First test samples now available. Test full cell ECM samples in your own lab or let us do it for you

Unique international team of experts

- Advanced material science research and development for electrolyzer cells
- Electro chemistry, nanotechnology, catalyst and corrosion science (9 PhDs)
- Scaling up nanotechnology production processes for industrial volumes and sizes

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SMOLTEK ECM™

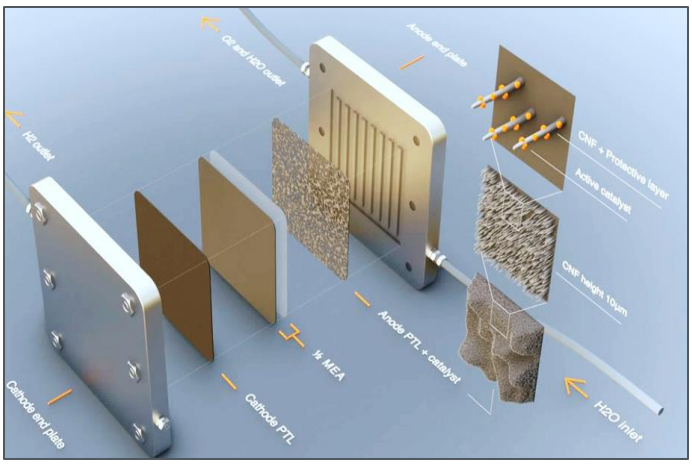
Porous transport electrode with 0.1 mg_{Ir}/cm^2

The catalyst coated electrode SMOLTEK ECM provides the ultra-low iridium loading levels that are required to develop and scale-up the next generation of PEM electrolyzers

ECM - Smoltek's iridium coated electrode

Nanofibers (CNF) are "grown" on a porous transport layer (PTL) and covered in corrosion protection, before iridium is deposited.

With cathodic electrodeposition the morphology and deposition process of Ir are controllable at very low loading amounts (e.g. 0.1 mg_{Ir}/cm^2)



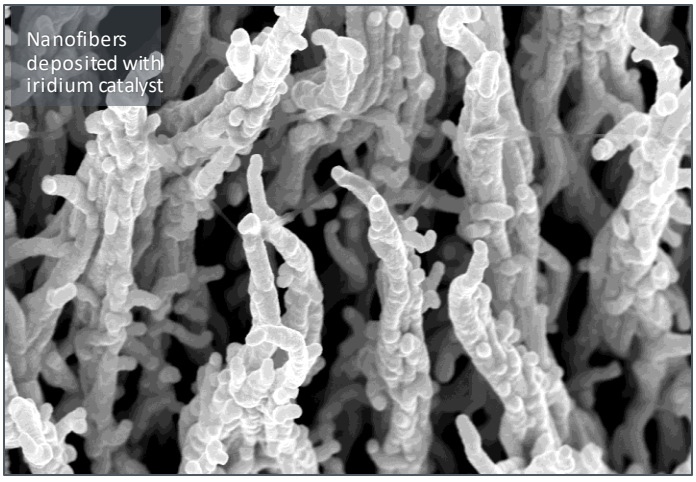
Breakthrough solves iridium shortage

Smoltek´s electrode was developed to help PEM electrolyzer manufacturers dramatically reduce the amount of non-active iridium particles.

Smoltek use nanofibers to maximize the anode surface area and increase the utilization ratio of the catalyst surface.

It is expected to reach 2A/cm^2 with 0.1mg_{Ir}/cm^2 during 2023.

No performance compromise, just less iridium.



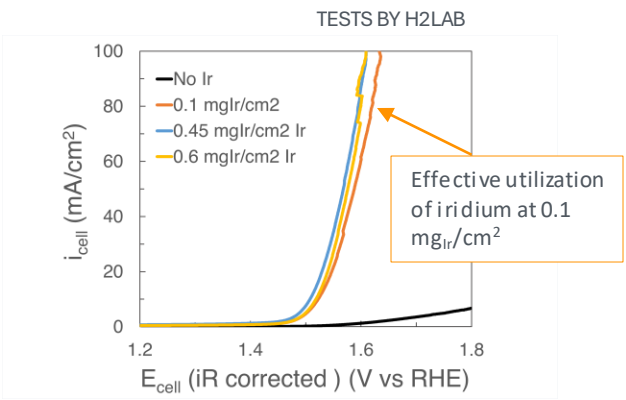
SMOLTEK ECM
Anode Porous Transport Electrode
PEM Electrolyzer Cell Material with 0.1 mg Ir/cm^2

ULTRA-LOW IRIDIUM LOADING

Smoltek's latest test results on the way to 0.1 mg_{Ir}/cm^2

Half cell tests already reached 0.1 mg/cm²

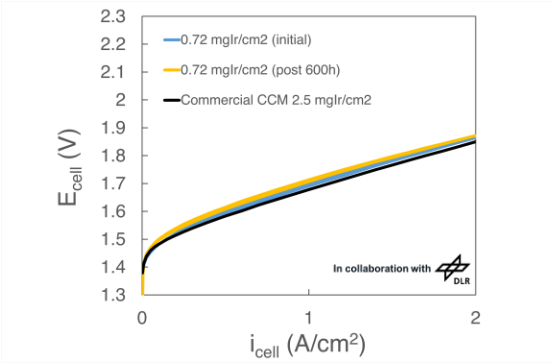
The Oxygen Evolution Reaction (OER) analysis on half-cell test shows us that our material can reach high current density from high to low Ir loading (0.6 to 0.1 mgIr/cm²).



Linear Sweep Voltammetry (LSV) curves in a half-cell

Same performance as 2.5 mg_{Ir}/cm^2

On full-cell test, we obtain a polarization curve at 0.7 mgIr/cm² close to that of a commercial material at 2.5 mgIr/cm².

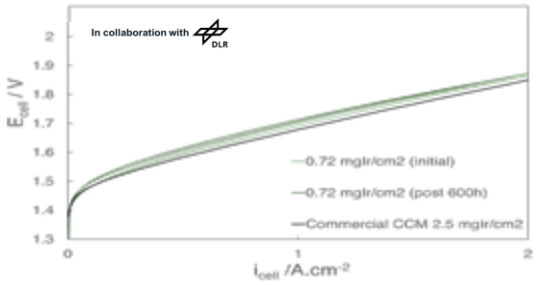


Polarization curves (JRC protocol) at different Ir loadings

No degradation after 600 hours

After a 600h stability test, we also observe that our material doesn't suffer any irreversible degradation

Polarization curves (from JRC protocol) at after a 600h stability test



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SMOLTEK ECM™ - COMPACT CONFIGURATION

Technology for the downsized PEM electrolyzer

With longer nanofibers the catalytic surface area is increased, making higher current density possible. More GW per m^2 cell area – this is what we call COMPACT

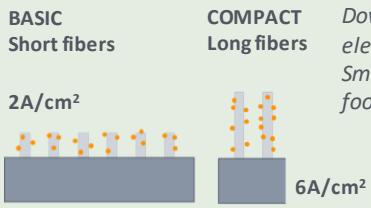
EXAMPLE – Three times longer fibres in Smoltek's coating

PRODUCT ADVANTAGES

1. Higher Capacity

With 3 times longer fibers we could increase current density to 6 A/cm^2 instead of 2 A/cm^2

2. Smaller footprint



Downsized electrolyzers - Smaller footprint

3. Manufacturing Cost

STRATEGIC ADVANTAGES

1. Three times faster scaling up

With three times higher current density, a three times smaller cell stack deliver the same output

2. Unique product performance

With a current density of 6 A/cm2, unique electrolyzers can be developed

- Cheaper hydrogen production facilities
- Smaller foot-print with same capacity
- High capacity at standard size

3. Unique cost position

An electrolyzer built with the high-density ECM use significantly smaller stacks

keur/m^2	Classic solutions CCM	Smoltek BASIC 3µm	Smoltek COMPACT 10µm
Cell	20	12	4
Balance of plant	12	12	12
Electrolyzer	32	24	16
			50%

Investment costs of new hydrogen plants can potentially be reduced up to 50%

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PEM Electrolyzer Cell Material with 0.1 mg Ir/cm^2

PROTECTING NANOFIBERS WITH Pt & ALD

The nanostructures are fully protected against corrosion

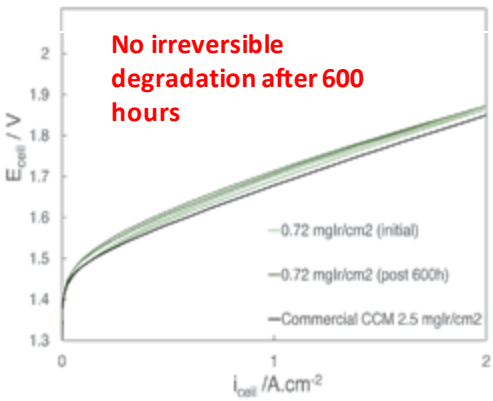
Atomic layers of platinum

Our vertically aligned CNFs are protected against corrosion by an ultra-thin conformal layer of platinum.

Atomic layer deposition (ALD) is used to place platinum on the nanofibers, to get the most precise surface possible. Since the nanofibers are covered with Pt atomic layer by layer, there are no empty areas where corrosion protection is missing.

This quality coating cannot be achieved on high aspect nanostructures with ordinary spray coating, resulting only in partial coverage or too thick films.

Successful full-cell durability test



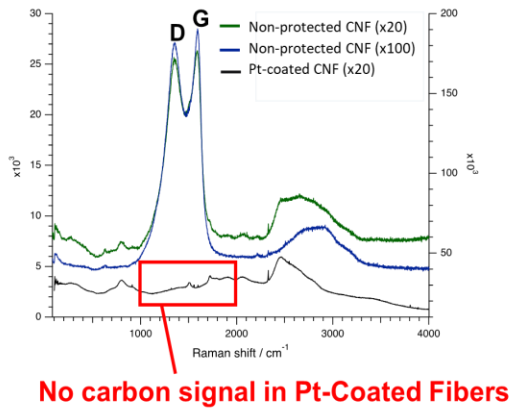
Stability test 60˚C, at 2 A/cm² No irreversible degradation

Raman analysis shows that the carbon nanofibers are completely covered

Raman spectroscopy is a technique to identify graphitic vibration resonances and thereby analyse the content of a sample

Non-protected carbon nanofibers
- The D and G modes of carbon are recognized as two peaks on Raman analysis

Platina-protected carbon nanofibers
- The peaks do not appear after a full Raman analysis of the surface of Pt-protected carbon nanofibers.
- We can expect our fibers to be completely covered and protected, avoiding most corrosion problems.



Raman analysis of the full surface of Smoltek's non-coated and Pt-protected CNFs

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ECS244 8TH – 12TH October 2023 Gothenburg

This printed material is meant to be used for discussions between Smoltek Hydrogen and other participants at the ECS244 meeting. It reflects the current results and status, but Smoltek Hydrogen is a young curious company in fast change, so do not expect everything you read here to be our latest knowledge when you read it later. Instead, get in direct contact on phone or email and we will be happy to share the latest news with you.

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